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THE ELEMENTS OF CHEMISTRY.

BY

THOMAS THOMSON, M.D. F.R.S.E.

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ADVERTISEMENT.

My intention in the following little Treatise, was to furnish an accurate Outline of the present state of Chemistry, to those persons who are commencing the study of the Science, or who may be unable or unwilling to peruse my larger and more complete work on the subject. All historical details, and all references to authorities were out of the question. My sole object was to include the greatest possible number of facts within the smallest possible space, and to arrange them in a clear and perspicuous manner. And though a variety of Chemical epitomes have appeared, both in this country and on the Continent, possessed, many of them, of much merit, and doing great credit to their authors, yet I flatter myself, that I may say with confidence, that there is hardly any of them that contains the same quantity of matter within so small a space. My view in the present Treatise, was limited to present a useful little book to Students, and to furnish them with a great number of important facts in a small space, and at a small expence. How far I have succeeded in my endeavours, I must leave to the determination of my Readers.

CONTENTS.

BOOK I. OF SIMPLE SUBSTANCES 1

DIVISION I. *Of confinable bodies* 2

Chap. I. Of Simple Supporters of Combustion.. 2

Sect. 1. *Of Oxygen*.......................3

Chap. II. Of Simple Combustibles 4

Sect. 1. *Of Hydrogen* 5

2. *Of Carbon and Diamond* 6

3. *Of Phosphorus*...................9

4. *Of Sulphur*......................11

5. *Of Boracium* 15

Chap. III. Of Simple Incombustibles...........18

Sect. 1. *Of Azote* 19

2. *Of Muriatic Acid*..................21

Chap. IV. Of Metals..........................24

Sect. 1. *Of Gold*..........................28

2. *Of Platinum*.......................30

3. *Of Silver*..........................32

4. *Of Mercury*........................34

5. *Of Palladium* 37

6. *Of Rhodium* 38

7. *Of Iridium* 39

8. *Of Osmium* 40

9. *Of Copper*........................41

10. *Of Iron*...........................44

11. *Of Nickel* 49
12. *Of Tin* 50
13. *Of Lead* 53
14. *Of Zinc* 56
15. *Of Bismuth* 59
16. *Of Antimony* 60
17. *Of Tellurium* 62
18. *Of Arsenic* 62
19. *Of Cobalt* 64
20. *Of Manganese* 65
21. *Of Chromium* 67
22. *Of Uranium* 67
23. *Of Molybdenum* 68
24. *Of Tungsten* 69
25. *Of Titanium* 70
26. *Of Columbium* 71
27. *Of Cerium* 72
28. *General Remarks* 72

DIVISION II. *Of unconfinable bodies*........

Chap. I. Of Light 77
II. Of Caloric 80
Sect. 1. *Of the nature of Caloric* 81
2. *Of the motion of Caloric* 82
3. *Of the equal distribution of temperature* 89
4. *Of the effects of Caloric* 90
5. *Of the quantity of Caloric in bodies* .. 98
6. *Of the sources of Caloric* 104

BOOK II.

OF COMPOUND BODIES 112
DIVISION I. *Of salifiable bases* 113
Chap. I. Of Volatile Alkalies 113
Sect. 1. *Of Ammonia* 114
Chap. II. Of Fixed Alkalies 117

Sect. 1. *Of Potash* 117
2. *Of Soda* 120
Chap. III. Of the Alkaline Earths..............122
Sect. 1. *Of Lime*........................122
2. *Of Magnesia* 125
3. *Of Barytes*........................126
4. *Of Strontian* 127
Chap. IV. Of the Earths Proper..............128
Sect. 1. *Of Alumina* 128
2. *Of Yttria* 130
3. *Of Glucina*........................131
4. *Of Zirconia* 132
5. *Of Silica*........................133
DIVISION II. Of primary compounds.........134
Chap. I. Of Oxides........................134
Sect. 1. *Of the Oxide of Hydrogen*..........135
2. *Of Carbonic Oxide*................137
3. *Of the Oxides of Azote*............138
Chap. II. Of Acids........................142
Class 1. *Acid Products*....................144
Sect. 1. *Of Sulphuric Acid*................145
2. *Of Sulphurous Acid*..............146
3. *Of Phosphoric Acid* 148
4. *Of Phosphurous Acid* 148
5. *Of Carbonic Acid* 149
6. *Of Boracic Acid*................151
7. *Of Fluoric Acid*................152
Class 2. *Acid Supporters*................153
Sect. 1. *Of Nitric Acid* 154
2. *Of Nitrous Acid*................156
3. *Of Oxymuriatic Acid*............157
4. *Of Hyperoxymuriatic Acid* 159
5. *Of Arsenic Acid*................160
6. *Of Tungstic Acid* 161
7. *Of Molybdic Acid*................161
8. *Of Chromic Acid*................162

9. *Of Columbic Acid*..............162

Class 3. *Combustible Acids* 163

Sect. 1. *Of Acetic Acid*..............164

2. *Of Benzoic Acid*..............166

3. *Of Sebacic Acid*..............166

4. *Of Succinic Acid* 167

5. *Of Moroxylic Acid*..............168

6. *Of Camphoric Acid* 168

7. *Of Oxalic Acid* 168

8. *Of Mellitic Acid*..............169

9. *Of Tartaric Acid* 170

10. *Of Citric Acid* 171

11. *Of Kinic Acid*..............171

12. *Of Saclactic Acid* 172

13. *Of Uric Acid*..............172

14. *Of Malic Acid*..............173

15. *Of Suberic Acid*..............174

16. *Of Formic Acid*..............174

CHAP. III. Of Colorific Acids..............175

Sect. 1. *Of Prussic Acid*..............175

2. *Of Gallic Acid*..............178

3. *Of Tannin*..............179

CHAP. IV. Of Compound Combustibles..............186

Sect. 1. *Of Alcohol* 186

2. *Of Ethers* 190

3. *Of Volatile Oils*..............197

4. *Of Fixed Oils*..............199

5. *Of Bitumens* 203

DIVISION III. *OF SECONDARY COMPOUNDS*..............206

CHAP. I. Of Combinations of Earths..............207

CHAP. II. Of Glass..............208

CHAP. III. Of Salts..............211

Sect. 1. Of Alkaline and Earthy Salts..............213

Genus 1. *Muriates* 215

2. *Fluates*..............218

3. *Borates* 220

4. *Phosphates* 221

5. *Phosphites* 224

6. *Carbonates* 225

7. *Sulphates* 228

8. *Sulphites* 233

9. *Nitrates* 235

10. *Nitrites* 239

11. *Oxymuriates* 239

12. *Hyperoxymuriates* 239

13. *Arseniates* 241

14. *Arsenites* 242

15. *Molybdates* 242

16. *Tungstates* 243

17. *Chromates* 243

18. *Columbates* 244

Order II. Combustible Salts....................244

Genus 1. *Acetates* 244

2. *Benzoates* 246

3. *Succinates* 246

4. *Moroxylates*....................246

5. *Camphorates* 247

6. *Oxalates* 248

7. *Mellates* 250

8. *Tartrates*....................250

9. *Citrates*....................253

10. *Kinates* 254

11. *Saccolates* 254

12. *Sebates*....................254

13. *Urates* 254

14. *Malates* 255

15. *Formiates* 255

16. *Suberates*....................255

17. *Gallates* 255

18. *Prussiates* 256

Sect. 2. Of Metalline Salts....................256

Genus 1. *Salts of Gold*....................257

2. *Salts of Platinum* 258

Genus 3. *Salts of Silver* 259
4. *Salts of Mercury*........................262
5. *Salts of Palladium*........................266
6. *Salts of Rhodium*........................266
7. *Salts of Iridium*........................266
8. *Salts of Osmium*........................267
9. *Salts of Copper*........................267
10. *Salts of Iron*........................270
11. *Salts of Tin*........................274
12. *Salts of Lead*........................276
13. *Salts of Nickel*........................280
14. *Salts of Zinc*........................281
15. *Salts of Bismuth*........................283
16. *Salts of Antimony* 285
17. *Salts of Tellurium* 286
18. *Salts of Arsenic*........................287
19. *Salts of Cobalt*........................288
20. *Salts of Manganese* 289
21. *Salts of Chromium* 290
22. *Salts of Molybdenum*........................290
23. *Salts of Uranium* 291
24. *Salts of Tungsten* 292
25. *Salts of Titanium* 292
26. *Salts of Columbium* 293
27. *Salts of Cerium*........................293

CHAP. IV. Of Hydrosulphurets........................295

CHAP. V. Of Soaps 299

Sect. 1. *Of Alcaline Soaps*........................299
2. *Of Earthy Soaps* 301
3. *Of Metallic Soaps*........................301

DIVISION IV. *OF VEGETABLE SUBSTANCES*....302

CHAP. I. Of Acids 304
II. Of Sugar 306
III. Of Sarcocoll 310
IV. Of Asparagin 311

CHAP. V. Of Gum 312
VI. Of Mucus............................316
VII. Of Jelly 317
VIII. Of Ulmin 318
IX. Of Inulin............................319
X. Of Starch 320
XI. Of Indigo............................324
XII. Of Gluten............................330
XIII. Of Albumen............................334
XIV. Of Fibrin 336
XV. Of the Bitter Principle............337
XVI. Of Tannin 342
XVII. Of the Extractive Principle....343
XVIII. Of the Narcotic Principle....346
XIX. Of Oils............................349
XX. Of Wax............................353
XXI. Of Camphor............................356
XXII. Of Bird-lime 360
XXIII. Of Resins............................363
XXIV. Of Guaiacum 374
XXV. Of Balsams............................376
XXVI. Of Caoutchouc............................382
XXVII. Of Gum Resins 385
XXVIII. Of Cotton 390
XXIX. Of Suber............................391
XXX. Of Wood............................392
XXXI. Of Alkalies 393
XXXII. Of Earths............................394
XXXIII. Of Metals............................395

DIVISION V. *Of animal substances*.........396

CHAP. I. Of Animal Substances 397
Sect. 1. *Of Gelatine*............................397
2. *Of Albumen*............................400
3. *Of Mucus* 405
4. *Of Fibrin* 407
5. *Of Urea*............................409

6. *Of Saccharine Matter*.............413
7. *Of Oils*.......................415
8. *Of Resins* 417
9. *Of Acids*......................419
10. *Of Earths and Metals*............ 422
* Chap. II. Parts of Animals......................423
Sect. 1. *Of Bones, Shells and Crusts*........425
2. *Of Horns, Nails and Scales*........430
3. *Of Muscles of Animals*............432
4. *Of the Skin*.....................434
5. *Of Membranes, Tendons, Ligaments and Glands*.................437
6. *Of the Brain and Nerves*..........438
7. *Of Marrow*......................440
8. *Of Hair and Feathers*..............442
9. *Of Blood* 445
10. *Of Milk*.......................448
11. *Of Saliva*......................453
12. *Of Bile* 454
13. *Of the Cerumen of the Ear*........458
14. *Of Tears and Mucus*.............. 459
15. *Of the Liquor of the Pericardium*460
16. *Of the Humours of the Eye*........461
17. *Of Sinovia* 462
18. *Of Semen* 464
19. *Of Animal Poisons*...............466
20. *Of Sweat*.......................468
21. *Of Urine*.......................471
26. *Of Morbid Concretions*............475

BOOK III.

OF AFFINITY.......................478
Chap. I. Of Gases...........................480
—— II. Of Liquids 488
—— III. Of Solids 490
Table of Chemical Decompositions.................494

THE

ELEMENTS

OF

CHEMISTRY.

THE object of Chemistry is to ascertain the ingredients of which bodies are composed, to examine the compounds formed by the combination of these ingredients, and to investigate the nature of the power which occasions these combinations. It may be divided into three parts: 1. A description of the component parts of bodies, or of *simple substances*. 2. A description of *compound* bodies. 3. An account of the power which occasions combinations. This power is called *affinity*. These three particulars form the subject of the three following books.

BOOK I.

OF SIMPLE SUBSTANCES.

We are probably ignorant at present of bodies, strictly speaking, elementary or simple. All that is understood in

Chemistry by a *simple substance,* is a substance not yet decomposed, and which we cannot shew to be a compound. Those of that kind at present known are about 48. They may be divided into two classes ; those which can be confined in vessels, and of course exhibited in a separate state; and those which cannot be confined in any vessels that we possess, and the existence of which is only inferred from certain phenomena exhibited by the first class of bodies in certain circumstances. The first class of bodies may be called *confinable,* the second *unconfinable.*

DIVISION I.

OF CONFINABLE BODIES.

The confinable bodies may be arranged under the four following heads :

1. Simple supporters of combustion.
2. Simple combustibles.
3. Simple incombustibles.
4. Metals.

These classes shall be treated of in order in the four following chapters.

CHAP. I.

OF SIMPLE SUPPORTERS OF COMBUSTION.

The term, *Supporter of Combustion,* is applied to those substances which must be present before combustible substances will burn. Thus *air* is a supporter of combustion, because a candle will not burn unless it be supplied with air.

All supporters, not yet decompounded, are called *simple*. We know only one such body, namely *oxygen*.

SECT. I. *Of Oxygen.*

This substance is an *air*, or, as chemists use to call aërial bodies, a *gas*.* It was discovered by Dr Priestley. It may be obtained by heating *black oxide of manganese* in an iron bottle fitted with a long iron tube. The extremity of the tube is plunged into a trough of water having a shelf a little below the surface, on which stands an inverted glass cylinder full of water. The open mouth of this cylinder is brought over the extremity of the iron tube. As soon as the manganese is red hot, air issues from the extremity of the tube, and gradually fills the glass vessel, displacing the water. In this way any quantity of oxygen gas may be procured. Red lead or red precipitate may be substituted for the manganese, but they do not yield so much oxygen. The salt called hyperoxymuriate of potash may also be used, and it yields a very great proportion of oxygen. Oxygen gas may also be obtained by putting the manganese in powder into a glass retort and pouring on it as much *sulphuric acid* as will make it into a thin paste. The heat of a lamp being applied to the retort while its beak is plunged into the water trough, the gas is disengaged in considerable quantity.

Oxygen gas possesses the mechanical properties of common air. It is colourless, invisible and capable of indefinite expansion and compression.

Combustibles burn in it better and brighter than in common air. Animals can breathe it longer than common air without suffocation.

---

* The term *gas* is applied by chemists to all *airs* except *common air*.

It has been ascertained, that one-fifth of the air of the atmosphere is oxygen gas, and that when this portion is abstracted, the air can neither support combustion nor animal life.

When substances are burnt in oxygen gas or air, or when animals breathe them, a portion of the oxygen always disappears, and, in some cases, even the whole of it.

Its specific gravity, according to Kirwan, is 1·103, according to Davy 1·127, according to Fourcroy, Vauquelin and Seguin 1·087, that of air being 1·000. At the temperature of 60°, and when the barometer stands at 30 inches, 100 cubic inches of common air weigh very nearly 31 grains troy. 100 cubic inches of oxygen in the same temperature and pressure, weigh, according to these results, 34 grains, 34·74 grains and 33·69 grains troy.

It is not sensibly absorbed by water. 100 cubic inches of water freed from air by boiling, absorb 3·55 inches of this gas.

Oxygen is capable of combining with a great number of bodies, or it has an *affinity* for them, and forms compounds with them.

CHAP. II.

OF SIMPLE COMBUSTIBLES.

By *combustible* is understood a substance capable of burning; and by *simple combustibles*, bodies of that nature not yet decomposed. They are five in number, namely *hydrogen*, *carbon*, *phosphorus*, *sulphur* and *boracium*. It is not improbable that the bases of all or most of these substances are metals; but the opinion has not yet been made out in a satisfactory manner.

SECT. I. *Of Hydrogen.*

Hydrogen, like oxygen, is a gas. It was first called *inflammable air*, and Mr Cavendish must be considered as its real discoverer.

It may be procured by putting some clean iron filings into a glass retort, and pouring over them sulphuric acid diluted with thrice its bulk of water. A violent boiling takes place, or, as chemists term it, an *effervescence*, gas issues abundantly from the beak of the retort, and may be received like the oxygen in glass vessels standing in a trough of water.

It is invisible and colourless, and possesses the mechanical properties of common air.

When prepared by the above process, it has a peculiar smell, ascribed at present to the presence of a little *oil*, formed by the action of the acid on the iron filings.

It is the lightest gaseous body known. Its specific gravity, according to Kirwan, is 0.0843, according to Lavoisier, 0.0756, according to Fourcroy, Vauquelin and Seguin 0.0887. According to these various estimates, 100 cubic inches under the mean pressure and temperature weigh 2.613 grains, 2.372 grains and 2.75 grains Troy. It is about 12 times lighter than common air.

No combustible substance will burn in it; and no animal can breathe it for any length of time without death.

It burns when touched with a red hot iron, or when brought near a flaming taper. The colour of the flame is yellowish, and it gives but little light. If it be previously mixed with half its bulk of oxygen gas, it burns instantaneously, and with a loud explosion like the report of a pistol. If the mixture be put into a strong glass cylinder, standing over water, and kindled by an electric spark, the whole of the two gases disappear, and the cylinder is filled with the water. If the vessel be standing over mercury, or be hermetically sealed, its inner surface becomes coated with pure water. This water was found by Cavendish equal in weight to the two gases. Hence it has been inferred, that water is a compound of oxygen and hydrogen in the proportion of $85\frac{2}{3}$ by weight of oxygen to $14\frac{1}{3}$ of hydrogen.

Hydrogen is not sensibly altered or absorbed by water. 100 cubic inches of water deprived of air absorb 1.53 inches of hydrogen.

SECT. II. *Of Carbon and Diamond.*

If a piece of wood be heated to redness in an iron bottle, or a crucible filled with sand, it is converted into a black brittle substance called *charcoal,* the properties of which are nearly the same from what wood soever it has been obtained, provided it has been exposed to a sufficiently strong heat.

Charcoal is insoluble in water, and not affected (provided air be excluded) by the most violent heat that can be applied.

It conducts electricity, is not liable to putrify, deprives meat of its putrid taste and smell, and is an excellent tooth powder.

It absorbs moisture with avidity, and likewise common air, oxygen and hydrogen gas; but less of the last than of the two former.

When heated to 802°, it takes fire, and, if pure, burns all away without leaving any residuum. If the experiment be made in a glass vessel filled with oxygen gas, and the charcoal be heated by means of a burning glass, the bulk of the oxygen gas is not altered, but a portion of it is converted into another gas possessing quite different properties. It renders lime water milky, and is quite absorbed by it, and cannot be breathed without occasioning instant death. This gas is called *carbonic acid.* It very nearly equals in weight the charcoal and the oxygen which have disappeared. Hence it is considered as a compound of them, and from the proportion of each employed, it is considered as composed of very nearly 28 parts of charcoal and 72 of oxygen.

When considerable quantities of charcoal are burnt in this manner, a portion of water also appears. Hence it is conceived, that charcoal contains a small portion of hydrogen. The constituent which constitutes by far the greatest part of it is called *carbon*. This supposition is corroborated by the late experiments of Mr Davy. Carbon exists in two other states, namely the diamond and plumbago.

2. The diamond is a precious stone, transparent, and often crystallized in a six sided prism, terminated by six sided pyramids. It is the hardest of all bodies. Its specific gravity is about 2·3. It is a non-conductor of electricity.

When heated to the temperature of 14° of Wedgewood's byrometer, or not so high as the melting point of silver, it gradually wastes away and burns. It combines with nearly the same quantity of oxygen, and forms the same proportion of carbonic acid as charcoal. Hence it consists chiefly of carbon. From the experiments of Davy, there is reason to believe that it contains a minute portion of oxygen as one of its constituents. The other constituent is carbon.

3. Plumbago, called also *black lead* and *graphite*, is well known as the substance of which pencils are made. It is dug out of the earth. It is of a dark blue colour, and has some metallic lustre. It is soft, brittle and infusible. When heated to redness, it gradually wastes away, and is converted into carbonic acid, leaving a little iron behind. It seems a compound of pure carbon, with about one 20th part of its weight of iron *.

Carbon combines with hydrogen, and forms a gas formerly called heavy *inflammable air*, now carbureted hydrosily cut with a knife. It is insoluble in water. Its specific gravity is 1·770.

---

* From the recent experiments of Thenard and Gay-Lussac, there is reason to believe that it contains a little hydrogen.

It melts at the temperature of 99°. It cannot easily be melted in the open air without taking fire. If air be excluded it evaporates at 219°. and boils at 554°.

When exposed to the air it emits a white smoke with the smell of garlic and is luminous in the dark. This smoke is more abundant the higher the temperature, and is occasioned by the gradual combustion of the phosphorus. In oxygen gas it is not luminous unless the temperature be as high as 80°. Hence we learn that it burns at a lower temperature in common air than in oxygen gas. This slow combustion in the open air renders it necessary to keep phosphorus in phials filled with water and well corked.

When heated to 148° it takes fire and burns with a vivid white flame and emitting a vast quantity of smoke. It leaves (if pure) no residuum, but the white smoke when collected is an *acid*, and is called *phosphoric acid.* If the combustion be conducted in a jar filled with oxygen gas, the oxygen will be found to diminish so much, that every 100 parts of phosphorus occasion the disappearing of 114 parts of oxygen. The acid formed weighs as much as the phosphorus and the oxygen which have disappeared. Hence it is considered as a compound of these two in the proportion of 100 parts of phosphorus to 114 of oxygen.

Phosphorus is supposed capable of combining with a small portion of oxygen and of forming a compound called *oxide of phosphorus.* It may be formed by putting a bit of phosphorus in a long glass tube and exposing it to the heat of boiling water. It *sublimes* and lines the tube in fine white flakes. This substance is very combustible and often takes fire of its own accord when exposed to the air.

When melted by means of a burning glass in hydrogen gas a portion of it is dissolved, and a new gas formed, first disc vered by Gemgembre, and called *phosphureted hydrogen gas.* It has a fetid odour like the smell of putrid fish. It burns spontaneously when it comes into contact with common air or oxygen gas. Water dissolves a small portion of this gas and acquires a bitter taste and unpleasant odour. The phosphorus gradually precipitates, and the hydrogen at the same time separates from the water. When kept in a glass jar it soon loses its property of burning spontaneously.

Phosphorus combines with charcoal and forms a compound of an orange red colour called phosphuret of carbon. Common phosphorus contains a portion of this compound which remains behind when the phosphorus is burnt. It is a light flocky powder without taste or smell. When heated sufficiently it burns, and the charcoal remains behind.

The compounds which phosphorus forms with other bodies are distinguished by the name of *phosphurets.*

Phosphorus is very poisonous when used internally. It has been recommended as a medicine, and said to be very efficacious in restoring the force of young persons exhausted by sensual indulgence.

From the experiments of Davy, it is very probable that common phosphorus contains hydrogen. Pure phosphorus deprived of its hydrogen would probably be metallic.

SECT. IV. *Of Sulphur.*

Sulphur, distinguished also by the name of *brimstone,* has been known since the earliest ages.

It is a hard brittle substance of a greenish yellow colour, without any smell and with very little taste. It is a nonconductor of electricity and becomes electric *negatively* by friction. Its specific gravity is 1·990. It is not altered by exposure to the air, nor is it soluble in water.

When heated to 170° it rises up in the form of a fine powred which may be easily collected and is called *flowers of sulphur*. It is then said to be *volatilized* or *sublimed*. It is obvious from this property that sulphur is a volatile substance.

When heated to about 218° it melts, becomes transparent and looks like a brown coloured oil. At 560° it boils, and the vapour kindles as it exhales and burns with a blue flame and an extremely disagreeable smell. If it be set on fire, and plunged into a jar filled with oxygen gas, it burns with a strong violet flame. In both cases (provided the quantity of air or oxygen be sufficient) it burns away completely without leaving any residue. But if the fumes be collected, they are found to be an acid which is known by the name of *sulphuric acid*. A portion of the oxygen disappears, and from the experiments of Lavoisier, it follows that the sulphuric acid formed is exactly equal in weight to the sulphur and the oxygen which have disappeared during the combustion. Hence it is concluded, that this acid is composed of these two substances united together.

Many experiments have been made to ascertain the composition of sulphuric acid exactly. The following is the result which appears to me most accurate. It was obtained by Klaproth.

100 sulphur.
136·5 oxygen.

236·5

But sulphur does not always combine with so great a portion of oxygen. It usually burns with a blue flame, and the suffocating vapours which it emits may be collected in glass cylinders filled with mercury, and standing in a trough containing mercury. They constitute a gas called *sulphurous* *acid.* They contain less oxygen than sulphuric acid. By my experiments they are compounded of

100 sulphur.
88·6 oxygen.

188·6

When sulphur is kept melted in an open crucible, it becomes gradually thick and viscid. If it be now poured into water, it assumes a purple colour, and remains for some days soft. But it gradually becomes brittle, and of a light violet colour. Its texture is fibrous, and its specific gravity 2·325. In this state it is called *oxide of sulphur,* from an opinion that it has combined with a little oxygen, and that this addition has altered its properties. From a set of experiments made by me on this substance, it follows that it is composed of 100 sulphur and 7 oxygen.

When sulphur is dissolved in any liquid, as in a solution of potash, and then precipitated by an acid, it is always in a state of a white powder, known by the name of *lac sulphuris.* This powder consists of sulphur combined with a little water. When the water is driven off by heat, the white colour of the sulphur disappears, and its natural yellow colour returns.

Sulphur combines readily with hydrogen gas, and forms a gas known by the name of *sulphureted hydrogen,* which was first described by Scheele.

It may be formed by mixing together *potash* and sulphur, and boiling them together in a glass flask. When sulphuric acid is poured into the yellowish coloured liquid that is formed, an effervescence takes place, and the gas may be collected in proper vessels.

Sulphureted hydrogen gas is colourless, and possesses the mechanical properties of common air. It has a strong fetid smell, like that of rotten eggs. It neither supports combustion, nor animal life. Its specific gravity, according to Kirwan, is 1·106, according to Thenard, 1·231. Water absorbs about its own weight of this gas, and acquires a fetid smell, a sweetish nauseous taste, and many of the properties peculiar to acids.

When this gas is set on fire, it burns with a reddish blue colour, and deposits a quantity of sulphur. When the electric spark is passed through it, sulphur is deposited, but the bulk of the gas is not altered. Sulphur is also deposited when *nitric acid* is dropt into water impregnated with it. When mixed with oxygen gas, and burnt, the only substances formed are sulphuric acid and water. Hence it is obvious that its constituents are sulphur and hydrogen. From an experiment of Thenard, not indeed susceptible of much accuracy, it seems to be composed of

100 hydrogen.
118 sulphur.

218

Sulphur acts upon charcoal at a red heat. If a quantity of charcoal be put into a porcelain tube, and heated to redness by passing it through a furnace, and sulphur be made to pass through it while in that state without any communication with the external air, a substance issues from the extremity of the tube, which may be obtained by means of a crooked glass tube luted to the porcelain tube, and plunged to the bottom of a glass vessel filled with water. This substance is a liquid colourless and transparent when pure, but often tinged greenish yellow. Its taste is cooling and pungent, and its odour strong and peculiar. It does not dissolve in water. Its specific gravity is 1·3. In an exhausted receiver, or at the top of a barometrical tube, it assumes the gaseous form. It burns very easily, and detonates when mixed with oxygen gas and kindled. It was first discovered by Lampadius and

Clement and Desormes; and Berthollet junior investigated its properties. It is composed of sulphur and hydrogen, but contains more sulphur than sulphureted hydrogen. It may therefore be called *supersulphureted hydrogen.*

Sulphur and phosphorus readily combine and in various proportions, but the compound seems to be most intimate when the weights of the two ingredients are equal. The combinations may be made by mixing the two ingredients in a small phial and melting them together, or by cautiously heating them in a flask filled with water. But the first method is less hazardous; for the compound acts upon the water and gases are formed which sometimes occasion violent explosions. The compound has a yellowish green colour; it may be distilled over in a glass retort without decomposition. It has a tendency to the liquid form, which is greatest when equal proportions of the constituents are used. It then remains liquid in the temperature of 41°. When the sulphur predominates in this compound, it may be called *phosphuret of sulphur;* when the phosphorus, *sulphuret of phosphorus.* It is very combustible and often takes fire spontaneously when exposed to the air.

From the experiments of Clayfield and Berthollet junior, there is reason to conclude that sulphur contains a small quantity of hydrogen, and Mr Davy has shewn that oxygen is also present in it. Hence it follows that the simple substance sulphur, which constitutes the base of sulphuric acid, has never yet been seen in a pure state.

SECT. V. *Of Boracium.*

This substance was discovered by Mr Davy, but it was first described by Thenard and Gay-Lussac. Mr Davy has just published a more detailed account of its properties. To procure it equal weights of the metal called *potassium* and dry *boracic acid* are to be put into a copper tube and exposed for some minutes to a slight red heat. When cold, the mass is to be washed out with water, the potash saturated with muriatic acid, and the whole thrown upon a filter. An olive coloured matter remains which must be washed and dried. It is *boracium.**

Boracium is of a dark olive colour, opake, brittle, its powder does not scratch glass, it is a non-conductor of electricity, and has some resemblance to charcoal. When heated to whiteness in a metallic vessel, it remains unaltered, provided common air or oxygen be excluded. After this process it sinks in strong sulphuric acid; but in its ordinary state it swims upon that liquid.

When heated in common air or oxygen gas to a temperature not quite so high as 600°, it takes fire and burns with considerable brilliancy, somewhat like charcoal, and is converted into boracic acid. By this process a portion of the oxygen disappears. Hence boracic acid is considered as a compound of boracium and oxygen. The exact proportion of the constituents of this acid have not yet been ascertained. According to Mr Davy's experiments, it is composed of one part boracium and two parts oxygen; while Thenard and Gay-Lussac consider it as a compound of two parts boracium and one of oxygen.

When placed in contact with oxymuriatic acid gas, it burns spontaneously with a white light, and is partly converted into boracic acid, partly into a black matter which is considered as an *oxide of boracium.* It burns when slightly heated, and is converted into boracic acid. It decomposes sulphuric and nitric acids with the assistance of heat, and is converted into boracic acid. When melted with sulphur and kept long in contact with it, a kind of combination takes place as the sulphur acquires an olive colour. It does not combine with phosphorus. Whether it combines with hydrogen and with charcoal has not been tried.

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* The French chemists have called it *bore.*

Potash and soda dissolve it both when liquid and when melted with it in a crucible, forming pale olive compounds which give dark-coloured precipitates when treated with muriatic acid. It did not combine with mercury by heat.

Mr Davy has rendered it probable that it contains a little oxygen, and that, when deprived of this principle, it combines with metals and forms compounds capable of conducting electricity. Hence he is inclined to believe, that if it could be obtained pure, it would be of a metallic nature: a supposition by no means improbable, not only with respect to boracium, but almost all the simple combustibles.

SUCH are the properties of the simple combustible bodies; none of which, unless hydrogen be an exception, are, strictly speaking, simple substances, though we are not in possession of any accurate method of separating their constituents and exhibiting them in a separate state. It is even possible, though not very likely, that the hydrogen and oxygen separated from several of them, may be owing to the presence of water in them, from which it is very difficult to separate them completely.

Two of them, *boracium* and *carbon*, are solids which we are incapable of melting or altering by heat; two of them, sulphur and phosphorus, easily melt, and may be exhibited in a solid, liquid, or even gaseous state; while one of them, hydrogen, is always, when pure, in the state of a gas.

They all combine with oxygen, but in different proportions, as is obvious from the following table, exhibiting the quantity of oxygen capable of combining with 100 parts of each.

100 Hydrogen unites with 600 oxygen.
100 Carbon — — 257
100 Boracium — — 200
100 Sulphur — — 138·7
100 Phosphorus — — 114

It has been supposed by some that the affinity of different bodies for oxygen, is proportioned to the quantity of it with which they combine. According to this notion, the affinity of the simple combustibles for oxygen, is in the order of the preceding table.

Hydrogen unites to oxygen as far as is known only in one proportion, boracium and carbon in two, phosphorus and sulphur in three.

Hydrogen unites with all the simple combustibles, unless boracium be an exception. It is probable that they are all capable of combining with each other at least in one proportion, and some are known to combine in several. Chemists have agreed to give such compounds a name derived from one of the ingredients and ending in *uret*, as *sulphuret of phosphorus, phosphuret of carbon.* When the compound is gaseous, the term is converted into an adjective, as *sulphureted hydrogen gas, carbureted hydrogen gas.*

CHAP. III.

OF SIMPLE INCOMBUSTIBLES.

By simple incombustibles are meant all substances incapable of combustion which have not yet been decomposed. We are acquainted with only two such bodies at present, namely *azote* and *muriatic acid.* There can be little doubt that both are compounds, though hitherto all attempts to analyse them have failed.

SECT. I. *Of Azote.*

1. AZOTE, called also *nitrogen*, which was first particularly pointed out by Dr Rutherford in 1772, constitutes four-fifths of the atmosphere. The other fifth is oxygen. To obtain it pure, we have only to deprive any portion of air of the whole of its oxygen. This is easily done by confining in it for some time a mixture of sulphur and iron filings made up into a paste, or a quantity of phosphorus.

Azotic gas is invisible, and possesses the mechanical properties of common air. Its specific gravity, according to Kirwan, is 0·985; according to Lavoisier 0·978; according to Biot and Arago 0·969; that of common air being 1·000.

It neither supports flame nor animal life. Water does not sensibly absorb it. 100 cubic inches of water, freed from air by boiling, absorb about 1½ inches of this gas.

2. Though incombustible it is capable of combining with oxygen gas. When electric sparks are passed through a mixture of oxygen and azotic gases for some time, the bulk of the mixture diminishes, and an acid is formed. If the gases be mixed in the proper proportions they disappear entirely, and are of course totally converted into an acid. This acid is the *nitric*. Hence it follows that nitric acid is composed of oxygen and azote. This important discovery was made by Mr Cavendish. The result of his experiments gives us nitric acid composed very nearly of

30 azote,
70 oxygen.
———
100

or one part azote united to 2⅓ of oxygen.

Nitric acid is a yellow corrosive liquid of great importance in chemistry. It acts with great energy on most other bodies, in consequence of the facility with which it parts with its oxygen. If copper or silver, for example, be put into it, the metals absorb oxygen and dissolve. The portion of acid which loses a part of its oxygen, assumes the gaseous form, and makes its escape out of the liquid occasioning an effervescence. The gas which escapes is a compound of azote and a smaller proportion of oxygen than exists in nitric acid. It is usually called *nitrous gas.* It has the curious property of combining with oxygen gas whenever it comes in contact with it, and of thus being again converted into nitric acid. The mixture becomes yellow, and, if standing over water, its bulk diminishes very much, because the water absorbs the acid as it forms.

If iron filings be kept for some days in a jar of nitrous gas its bulk diminishes, and it loses the property of becoming yellow when mixed with common air. Its properties are now changed and it is called *gazeous oxide of azote.* This new gas is composed of the same constituents as the former, but it contains a smaller proportion of oxygen. It supports combustion and bodies burn in it almost with as much splendour as in oxygen gas.

Thus it appears that azote has the property of combining with three different doses of oxygen.

3. The combinations of azote with the simple substances are not numerous, but some of them are important.

When putrid urine, wool, and many other animal substances are distilled, among other products there is obtained a substance of a pungent odour and taste, known by the names of *hartshorn, volatile alkali, ammonia.* It may be obtained pure by heating a mixture of three parts of quicklime and one part of the salt called *sal ammoniac* in a glass flask and receiving the product over mercury. It is a gas. When electric sparks are passed through it, its bulk is doubled, and it is converted into a mixture of azotic and hydrogen gases. Hence it was considered as a compound of these two substances; but the late experiments of Davy have rendered it very probable that it likewise contains oxygen.

Azotic gas is said to have the property of dissolving a little charcoal, which it again deposites when allowed to stand over water.

It dissolves likewise a little phosphorus and increases about 1-40th part in bulk. When this phosphureted azotic gas is mixed with oxygen gas it becomes luminous, in consequence of the combustion of the dissolved phosphorus.

Azotic gas is said likewise to dissolve a little sulphur when assisted by heat. Sulphureted azotic gas is said to resemble sulphureted hydrogen gas in its properties.

There is reason to believe, from the late experiments of Davy, that oxygen is one of the constituents of azote. But the nature of the other constituent is unknown. Some have supposed that it is hydrogen, and that azote differs from water merely in containing less oxygen. But this opinion has not been confirmed by any satisfactory experiment. Dr Priestley called this gas *phlogisticated air*, and considered it as a compound of oxygen and the supposed universal inflammable principle to which the name of *phlogiston* was given.

SECT. II. *Of Muriatic Acid.*

Muriatic acid, the second of the simple incombustibles, is a gas, and may be obtained by putting some common salt in a small glass retort, pouring over it sulphuric acid and receiving the product over mercury.

1. Muriatic acid gas is invisible, and possesses the mechanical properties of common air. Its specific gravity, accord-

ing to Kirwan, is 1·929, that of air being 1·000. Its smell is pungent and peculiar, and when mixed with air it forms a visible smoke, owing to its great avidity for moisture.

It does not support combustion, nor can it be breathed by animals. When a lighted taper is plunged into it, it goes out with a green coloured flame.

If a little water tinged blue by red cabbage, mallows, or litmus be let up into it, the blue colour is immediately changed into red. This change of colour from *blue* to *red*, is considered by chemists as characteristic of *acids*.

Water when brought into contact with this gas absorbs it with great rapidity, and the whole disappears. Water absorbs 515 times its bulk of this gas, and six cubic inches of water by this absorption are converted into nine. The affinity between this gas and water are very great. It always contains a great portion of water in the state of vapour, probably more than one-third of its weight, and all attempts to separate this water have failed. Water seems to be essential to the gaseous state of this acid.

Water saturated with this gas is known by the name of *liquid muriatic acid.* It has been long known and is very much employed by chemists. When pure it is transparent and colourless: but it very often has a greenish yellow colour, owing to the presence of iron or of some other impurity. It has the smell of muriatic acid gas, and smokes when exposed to the air. Its specific gravity is never greater than 1·203, and seldom exceeds 1·196; and when strongest never contains more than one-fourth of its weight of acid; the rest is water.

2. Muriatic acid combines with oxygen and forms with it two compounds of considerable importance, called *oxymuriatic acid* and *hyper-oxymuriatic acid.*

When liquid muriatic acid is poured upon the black oxide of manganese an effervescence takes place, and by the assistance of heat a gas is extricated of a green colour. It was discovered by Scheele, and is called *oxymuriatic acid gas.* It has an extremely offensive and noxious odour, and cannot be breathed without the most fatal effects. It supports combustion; indeed many substances, as phosphorus, take fire spontaneously when plunged into it. It destroys vegetable colours, and is, on that account, useful in bleaching. From the analysis of Chevenix it appears to be composed of

77·5 muriatic acid,
22·5 oxygen.

100

When a current of oxymuriatic acid is passed through water, holding potash in solution, a number of small shining crystals is gradually deposited. They constitute the salt called *hyper-oxymuriate of potash,* which possesses many curious properties. This salt is composed of potash and hyper-oxymuriatic acid, an acid which contains much more oxygen than the oxymuriatic. It has not yet been obtained separately. According to the analysis of Chevenix, it is composed of

34 muriatic acid,
66 oxygen,

100

3. The action of muriatic acid on the simple combustibles has not, hitherto, been examined with much attention.

Hydrogen is not acted on by it. Charcoal absorbs it rapidly; but the change produced by the absorption has not been examined. Phosphorus does not sensibly absorb it.

Sulphur imbibes it very slowly. When a current of oxymuriatic gas is made to pass over flowers of sulphur, the sulphur is gradually converted into a very volatile red coloured liquid, to which I give the name of *sulphureted* muriatic acid. Its specific gravity is 1·623. It smokes very strongly, has a strong smell, and is very volatile. It dissolves phosphorus readily. When mixed with water, it is decomposed, and a quantity of sulphur separates. It consists of muriatic acid, sulphur and oxygen, and I think it not improbable that the oxygen is combined with the sulphur constituting an oxide.

We are not acquainted with any action which muriatic acid has on azote. When mixed with nitric acid, it constitutes the compound acid called *aqua regia* or *nitro-muriatic acid.* Boracium tinges muriatic acid green, but does not act violently on it.

SUCH are the properties of the simple incombustibles. Like the combustibles they combine with oxygen. But they unite without combustion, and the compounds which they form are supporters. Azote unites with 3 doses of oxygen, while muriatic acid combines with two.

We know little of the action between the simple combustibles and incombustibles.

CHAP. IV.

OF METALS.

Metals, one of the most important classes of bodies, and to which we are indebted for most of our improvements, are very numerous. Indeed the present state of Chemical analysis leads to the opinion that all bodies will ultimately divide themselves into two sets; namely, *metals* and oxygen.

1. Metals are distinguished by a peculiar lustre, well known by the name of the *metallic lustre.* They are perfectly opake or impervious to light, even in the thinnest plates to which they can be reduced. The only exception is gold leaf. Its thickness does not exceed $\frac{1}{280000}$th part of an

inch, and it allows the light to pass through it. If other metals could be reduced as thin, it is probable that they also would be pervious to light. They may all be melted when heated sufficiently. Some, as mercury, require very little heat to melt them; while others, as platinum, require a great deal. Their specific gravity is exeeedingly various. All the old metals are at least 5 times heavier than water, and some, as platinum, more than 20 times heavier. But some of the new metals discovered by Davy are much lighter than water. They are the best conductors of electricity of all known bodies. None of them is very hard. But some of them may be hardened artificially, so as to exceed most other bodies. Their elasticity may likewise, in some cases, be artificially increased. Some of them are *malleable*, or may be extended by the blows of a hammer, while others are *brittle*. Some of them are *ductile*, or may be drawn out into wire, while others cannot. They differ considerably from each other in their *tenacity*, or in the weight which they are capable of supporting without breaking.

2. Several of them take fire when heated, and burn with considerable splendour, and almost all of them may be burnt by peculiar contrivances. After combustion their appearance is totally changed. They have lost the metallic lustre, and are converted into earthy-like powders, formerly called *calces*, and now *oxides*. These oxides are of various colours, white, red, yellow, blue, &c. according to the metal, and several of them are employed as paints. Most metals are converted into oxides, merely by exposing them for a sufficient length of time to the action of heat and air, and all by the action of acids.

When these oxides are mixed with charcoal powder, and heated, they lose their earthy-like appearance, and are restored again to the metallic state. This process is called *reduction*. Some metallic oxides, as those of gold and silver, require only to be heated in order to be *reduced;* but most of them require also the presence of charcoal or of some other combustible substance. These oxides were at first considered as simple substances, and the metals were supposed to be composed of them and the principle of inflammability, called phlogiston. But it was shewn by the experiments of Lavoisier, that the oxides are compounds, and that they are composed of the metals from which they were obtained, united to oxygen. Thus *oxide of gold* is a compound of gold and oxygen. It was the discovery of this fact that induced chemists to substitute the word *oxide* for calx.

Most metals are capable of combining with various doses of oxygen, and of forming various oxides, which it is of consequence to be able to distinguish. This may be done by prefixing to the term oxide, the Greek ordinal numeral, expressing the peculiar oxide. Thus *protoxide of tin* is the first oxide of tin, or tin combined with a minimum of oxygen. *Deutoxide of tin,* is the second oxide of tin, or tin combined with two doses of oxygen. The terms *tritoxide, tetroxide, pentoxide,* &c. are to be understood in the same way. The last oxide of a metal is called *Peroxide. Peroxide,* means a metal combined with as much oxygen as it can take up, or a metal saturated with oxygen.

3. Metals combine with the simple combustibles, and form compounds, many of which are of considerable importance. These compounds are denoted by a word formed from the simple combustible present, and terminating in *uret.* Thus *sulphuret of tin* is a compound of sulphur and tin. In like manner, *carburet* and *phorphuret of iron,* means iron combined respectively with carbon and with phosphorus. Hydrogen gas dissolves some of the metals. These solutions are denoted by prefixing the metal converted into an adjective before the word hydrogen. Thus *arsenical hydrogen gas,* means a solution of arsenic in hydrogen gas. When hydrogen

combines with a metal and forms a solid compound, it is denoted by the term *hydroguret*.

4. The metals are not known to combine with simple incombustibles. But they combine with each other, and form a set of important compounds, called *alloys*. Thus *brass* is an *alloy* of copper and zinc; and *bell metal* an *alloy* of copper and tin. When mercury is one of the metals combined, the compound is not called an alloy, but an *amalgam*. Thus the amalgam of gold, is gold dissolved in mercury.

5. The metals at present known (excluding the new ones discovered by Davy, which will be better described afterwards) amount to 27. They may be divided into the 4 following sets.

I. Malleable.

1. Gold.
2. Platinum.
3. Silver.
4. Mercury.
5. Palladium.
6. Rhodium.
7. Iridium.
8. Osmium.
9. Copper.
10. Iron.
11. Nickel.
12. Tin.
13. Lead.
14. Zinc.

II. Brittle, and easily fused.

1. Bismuth.
2. Antimony.
3. Tellurium.
4. Arsenic.

III. Brittle, and difficultly fused.

1. Cobalt.
2. Manganese.
3. Chromium.
4. Molybdenum.
5. Uranium.
6. Tungsten.

IV. REFRACTORY.

1. Titanium.
2. Columbium.
3. Cerium.

The fourth set consists of metals which have not hitherto been obtained in quantities, except in the state of oxides. Formerly the brittle metals were called *semimetals*, and the malleable, *metals*. The first four malleable metals were once considered as *noble*, because their oxides may be reduced by mere heat.

SECT. I. *Of Gold.*

Gold seems to have been the first known of all the metals. As it occurs always in the metallic state and is very soft and ductile, less skill would be necessary to work it.

1 Gold has a reddish yellow colour, considerable lustre, and is destitute of taste or smell. It is very soft. Its specific gravity is 19·376 that of water being 1·000. It is the most ductile and malleable of all known bodies. It may be beaten out into leaves only $\frac{1}{280000}$th part of an inch in thickness, and drawn out into wire extremely fine. Its tenacity is considerable, a gold wire 0·078 inch in diameter being capable of supporting 150·07 libs Avoirdupois without breaking.

It melts at 32° Wedgewood, and when melted has a bluish green colour. It does not sensibly waste nor alter, though kept very long in the state of fusion. In very violent heats however it has been perceived to be partially volatilized. When carefully cooled after fusion it sometimes crystallizes in four-sided pyramids. Gold is not altered by exposure to the air, it does not even lose its lustre.

2 It combines with oxygen and forms different oxides, the number and properties of which are but imperfectly known. Two have been described. The first purple is formed when violent electrical explosions are passed through gold leaf, or when gold is subjected to combustion. It is probably a compound of 100 gold and 8 oxygen.

The second or peroxide is of a yellow colour. It may be obtained by dissolving gold in nitro-muriatic acid and then precipitating the metal by means of lime water. It falls in the state of this yellow oxide. When carefully washed and dried it is insoluble in water and tasteless. I attempted to analyse it, but did not succeed. From an experiment of Proust we may infer that it is composed of 100 gold and 32 oxygen.

3. Hitherto gold has been united with only one of the simple combustibles, namely phosphorus. Hydrogen and charcoal are said to precipitate it from its solutions in the metallic state. With sulphur it does not combine. The action of boracium has not been tried.

The compound of phosphorus and gold is called *phosphuret of gold.* It may be formed by dropping small pieces of phosphorus into gold in fusion. It is brittle, whiter than gold, and contains $\frac{1}{24}$th of phosphorus. The phosphorus may be dissipated by exposing the compound to a sufficient heat.

4. As far as is known gold does not combine with either of the simple incombustibles.

5. It combines readily with most of the metals, and forms a variety of alloys.

Gold is so soft that is is seldom employed quite pure. It is almost always alloyed with a little copper or silver. Goldsmiths usually announce the purity of gold in the following manner. Pure gold is divided into 24 parts called *carats.* Gold of 24 carats means pure gold. Gold of 23 carats means 23 parts of gold alloyed with 1 part of some other metals; gold of 22 carats, 22 parts of gold alloyed with 2 parts of some other metal. The number of carats mentioned specifies the pure gold, and what that number wants of 24 indicates the quantity of alloy.

SECT. II. *Of Platinum.*

Platinum, which approaches gold in many of its properties was unknown in Europe as a peculiar metal till 1749. Hitherto it has been found only in South America and in the Silver mine of Guadal-canal in Spain. For the first accurate investigation of its properties we are indebted to Dr Lewis, and since his time it has been investigated by a great number of very eminent chemists.

It is brought from America in small flat grains having a silvery lustre. These grains besides platinum contain no less than 8 other metals. The platinum may be obtained pure by dissolving the grains in nitro-muriatic acid and pouring a solution of *sal ammoniac* into the liquid. An orange yellow precipitate falls. This precipitate is to be washed and dried and exposed to a red heat. The powder which remains is pure platinum. It may be amalgamated with mercury, and, by cautious heating and hammering, it may be reduced into an ingot.

1. Platinum has a white colour like silver, but not so bright. It is as hard as iron. Its specific gravity, when hammered, is at least 23, so that it is the heaviest of all known bodies. It is very ductile and malleable. A platinum wire of the diameter 0·078 inch, is capable of supporting 274·31 lbs. avoirdupois without breaking. It is very difficult of fusion, and indeed cannot be melted in any quantity by the greatest heat which we can produce. But at a white heat pieces of platinum may be welded together like pieces of hot iron. It is not altered by the action of heat and air.

2. Platinum cannot be converted into an oxide by the action of heat and air; we must have recourse to the action of acids. There are two oxides of platinum known: the protoxide is green, the peroxide brown.

The peroxide may be obtained by pouring lime water into the solution of platinum in nitro-muriatic acid. The brown powder which precipitates is to be dissolved in nitric acid, the solution evaporated to dryness, and the acid driven off by a cautious application of heat. The brown powder which remains is the peroxide. It is tasteless, insoluble in water, and decomposed by a red heat. It is composed, according to Mr Chenevix's experiments, of

87 platinum,
13 oxygen.
———
100

If the peroxide is gradually heated it assumes a green colour, owing to the separation of a quantity of oxygen. This green powder is the protoxide composed of

93 platinum,
7 oxygen.
———
100

3. The simple combustibles have but little action on platinum. Neither hydrogen nor carbon unites with it. Phosphorus combines readily and forms a *phosphuret*. It may be obtained by projecting phosphorus on red hot platinum. Its colour is silver white, it is very brittle and hard, and easily melts. The phosphorus may be driven off by heat. Platinum cannot be made to unite with sulphur. In this respect it resembles gold.

4. The simple incombustibles do not combine with platinum.

5. It combines with most of the other metals, and forms alloys, first examined by Dr Lewis.

Gold unites to it, but a strong heat is necessary to combine them uniformly. Platinum alters the colour of gold very much. An alloy of 4 parts of gold and one of platinum has the colour of pure platinum. The colour is much affected unless the platinum be less than $\frac{1}{17}$th of the gold. If such an alloy be digested in nitric acid the platinum is dissolved. Thus it is easy to detect any attempt to debase gold by the addition of platinum.

SECT. III. *Of Silver.*

Silver seems to have been known almost as early as gold.

1. It has a fine white colour, with a shade of yellow, and is remarkably brilliant when polished. It is rather harder than gold. Its specific gravity is about 10·510. In malleability and ductility it is inferior to none of the metals except gold. It may be hammered out into plates not more than $\frac{1}{100000}$th of an inch thick, and drawn out into wire finer than a human hair. A silver wire 0·078 inch thick, is capable of supporting 187·13 lbs. avoirdupois, without breaking. It melts when thoroughly red hot, or at the temperature of 22° Wedgewood. By a very violent heat it may be boiled, and partly volatilized. When cooled slowly it crystallizes in 4 sided pyramids.

2. By very long exposure to heat and air silver may be oxidized, but the process is so tedious and difficult that we cannot have recourse to it. There are two oxides of silver known, both of which have an olive green colour.

The peroxide may be formed by dissolving silver in nitric acid, and precipitating, by means of lime water. The powder which falls, when washed and dried, is the peroxide. It is tasteless and insoluble in water. When exposed to light or to heat, it is decomposed, and the silver reduced. It is composed of about

89	silver,
11	oxygen.
100	

The protoxide may be formed by heating the solution of silver in nitric acid in contact with a quantity of granular silver. It resembles the peroxide in colour, but its combination with nitric acid is more soluble.

3. Neither hydrogen nor carbon have been combined with silver, but it combines readily with sulphur and phosphorus.

When thin plates of silver and sulphur are laid alternately in a crucible, they melt by a moderate heat, and form sulphuret of silver. This compound is found in silver mines, or it exists *native*, as mineralogists term it. It has a dark grey colour, a metallic lustre, and the softness, flexibility, and malleability of lead. Its specific gravity is 7·2. It is composed of 85 silver, and 15 sulphur. When silver plate is long exposed, it contracts a thin covering of this substance. Hence the tarnish of silver is owing to its combining with sulphur.

Phosphuret of silver may be formed by projecting phosphorus into melted silver. It is white, composed of grains, breaks under the hammer, but may be cut with a knife. It is composed of four parts of silver and one of phosphorus. Heat decomposes it by dissipating the phosphorus.

4. Silver does not combine with the simple incombustibles.

5. It combines readily with most of the metals.

When gold and silver are melted together, they combine spontaneously, in the proportion of one part of silver and 5 of gold. They may, however, be melted together, and mixed in any proportion whatever. This alloy is harder and more sonorous than pure gold. Its hardness is a maximum when the alloy consists of two parts gold and one silver. The density of the alloy is a little diminished, and the colour of the gold is much altered, even when the proportion of silver is small. It is not only pale, but has a very sensible greenish tinge.

Silver and Platinum may be combined by fusion and form a hard alloy not so ductile as silver. The two metals separate when the alloy is kept in fusion. Hence there appears but little affinity between them.

SECT. IV. *Of Mercury.*

Mercury, called also *quicksilver,* was known to the ancients, and applied by them to the same purposes as it is by the moderns.

1. Its colour is white like that of silver; it has a good deal of lustre, and is destitute of taste and smell. Its specific gravity is 13·568. At the common temperature of the atmosphere it is always in a state of fluidity. But if it be cooled down to 39° below zero, it becomes solid like any other metal. The congelation of Mercury by cold was accidentally discovered by Professor Braun, at Petersburg, in 1759. The freezing point was ascertained by Mr Hutchins, at Hudson's bay, in consequence of the directions of Mr Cavendish. Solid mercury is malleable; but neither the degree of its malleability nor its ductility have been ascertained by experiment. Mercury boils when heated to 656°. Its vapour is invisible and elastic like air. It may be easily distilled over in proper vessels, and by this means is obtained pure.

2. Mercury is not altered by being kept in water. But when long agitated in air, or when kept heated in the open air, it gradually loses its metallic appearance and is oxidized. Only two oxides of mercury have been yet ascertained in a

satisfactory manner, the *protoxide*, which is *black*, and the *peroxide*, which is *red*.

The protoxide is a black powder, which may be obtained by agitating mercury for a long time in a stout phial; or by heating the salt called *calomel* or *muriate of mercury* with a solution of potash. It is black, insoluble in water, and contains about 5 per cent of oxygen.

The red oxide, called also *red precipitate*, may be obtained by keeping mercury for several days, nearly at the boiling point, in a tall glass vessel so contrived as to prevent the evaporation of the mercury and admit a communication between the anterior of the vessel and the atmosphere. The mercury becomes at first black and gradually changes to red. It may be formed more speedily and easily by dissolving mercury in nitric acid, evaporating the solution to dryness, and heating the dry salt gradually almost to redness in a crucible or capsule. Nitric acid fumes exhale, and the whole assumes a fine red colour. The red oxide of mercury has an acrid and disagreeable taste, acts as an escharotic and possesses poisonous qualities. When heated with zinc or tin filings it sets them on fire. It contains about 10 per cent of oxygen. When heated it gives out oxygen gas and the mercury is reduced.

3. Mercury does not combine with hydrogen or carbon; but it unites readily with sulphur and phosphorus.

When two parts of sulphur and one of mercury are triturated together in a mortar, they gradually assume the appearance of a black powder formerly called *æthiops mineral*. The same compound is formed by adding mercury slowly to its own weight of melted sulphur. When formed by the first process the powder is black, but a microscope detects in it small globules of mercury: when formed by the second process the powder is black, with a shade of purple. This compound has been ascertained to consist of mercury and sulphur united together, in what proportion is not well known.

When this black sulphuret is exposed to a red heat in a glass vessel it sublimes and forms a cake of a fine scarlet colour. In this state it is usually called *cinnabar*, and when reduced to a fine powder, *vermilion*. It is well known as a red paint. Its specific gravity is about 10. It is tasteless, insoluble in water and in muriatic acid. When suddenly heated it burns with a blue flame. When mixed with iron filings, and distilled, it is decomposed, and running mercury obtained in the receiver. It is composed of about 85 parts mercury and 15 sulphur.

When Phosphorus is mixed with the black oxide of mercury, and exposed to heat, the mixture readily combines, forming a black mass which seems to be phosphureted oxide of mercury. At least phosphorus and mercury do not unite when heated together.

4. Mercury does not unite with the simple incombustibles.

5. It combines with most metals, and forms compounds called *amalgams*.

The amalgam of gold is formed very readily by throwing small pieces of red hot gold into hot mercury. The two metals combine in any proportion. The amalgam is white and fluid if the mercury exceed. But by squeezing it through leather, the excess of mercury separates, and a solid amalgam remains, of the consistence of butter, which gradually crystallizes. It consists of one part of mercury to 2 of gold. This amalgam is much used in gilding.

The amalgam of platinum may be formed by triturating the powder of platinum with mercury, adding gradually a portion of either ingredient till the combination is completed. When the process of amalgamation is once begun it goes on easily. This amalgam has the consistence of butter, a white colour, much lustre, and does not tarnish by keeping. The mercury may be driven off by heat.

The amalgam of silver may be made in the same manner as that of gold, and with equal ease. It has a white colour, is always soft, and crystallizes.

All these amalgams are decomposed and the mercury driven off by heat.

SECT. V. *Of Palladium.*

This metal was lately discovered by Dr Wollaston in crude platina. Mr Chenevix announced soon after that he had succeeded in forming this metal artificially, by combining together platinum and mercury; but as no body has been able to repeat his experiment with success, we must suppose him mistaken.

To obtain palladium dissolve a sufficient quantity of crude platina in nitro muriatic acid, and pour a solution of the salt called *nitrate of mercury* into the liquid. A yellowish white powder falls. When this powder is washed and dried, and exposed to a red heat, it leaves a white matter which is *palladium*. When strongly heated with sulphur and borax it may be melted into a butter.

1. Palladium thus obtained is a white metal, very like platinum in its appearance. Its specific gravity, when hammered, is 11·871. It is as malleable as platinum, breaks with a fibrous fracture, and appears of a crystallized texture. It is not altered by exposure to the air, and a very violent heat is necessary to fuse it.

2. When kept strongly heated its surface acquires a blue colour. This is supposed a commencement of oxydizement. A more violent heat makes it resume the original metallic appearance. Sulphuric, nitric and muriatic acids dissolve a portion of it when assisted by heat, and assume each a red colour. Nitro-muriatic acid is the best solvent of it.

3. Neither hydrogen nor carbon combine with this metal. But when brought into contact with sulphur while red hot it melts immediately, and the sulphuret formed continues in fusion till only obscurely red. It is rather paler than the pure metal and very brittle.

4. The simple incombustibles do not combine with palladium ; but it unites with the metals, and forms alloys, which have been examined and described by Mr Chenevix.

SECT. VI. *Of Rhodium.*

This metal exists also in crude platina, and was discovered by Dr Wollaston still more recently than the last.

The process followed by Dr Wollaston for obtaining it, is somewhat complicated. Crude platina is dissolved in nitromuriatic acid, and the platinum prcipitated by sal ammoniac. A piece of clean zinc is immersed into the residuary solution which throws down a black powder. This black powder is digested with dilute nitric acid in a very gentle heat, to dissolve some copper and lead with which it is frequently contaminated. It is then dissolved in nitro muriatic-acid, common salt is added to the solution, and the whole is gently evaporated to dryness. The residuum is washed repeatedly with small quantities of alcohol, which dissolves two salts consisting of the oxides of platinum and palladium in combination with common salt. There remains behind a deep red-coloured substance consisting of the oxide of rhodium united to common salt. By solution in water and gradual evaporation rhomboidal crystals of a deep red colour are obtained. These crystals being dissolved in water, and a plate of zinc immersedi nto the solution, a black powder precipitates, which being strongly heated with borax becomes white, and assumes a metallic lustre. In this state it is *rhodium.*

1. Rhodium thus obtained is white. Its specific gravity exceeds 11. No degree of heat hitherto applied is sufficient to melt it. Of course its malleability and other similar properties are unknown.

2. It is not oxidized by exposure to heat and air. Neither is it much acted on by acids. The only oxide of rhodium known is of a yellow colour. It may be obtained by dissolving the red crystals mentioned above, and precipitating by means of potash. This oxide when dissolved in nitric or muriatic acid does not crystallize.

3. It unites readily with sulphnr and by that means is easily melted. When the sulphur is driven off by heat the metallic button obtained is not malleable. The action of the other simple combustibles is not known.

4. It does not combine with the simple incombustibles. It forms alloys with all the metals tried by Dr Wollaston, except mercury, with which it does not combine. It does not like platinum and palladium destroy the colour of gold when alloyed with it.

SECT. VII. *Of Iridium.*

This metal was discovered by Mr Smithson Tennant, in 1803. Attempts were made by Descotils, and by Fourcroy and Vanquelin soon after, to obtain the same metal, but they succeeded but imperfectly.

When crude platina is dissolved in nitro-muriatic acid a black powder remains, which preceding chemists considered as plumbago, but which Mr Tennant ascertained to be a compound of two new metals. When kept for some time in a red heat mixed with its own weight of potash in a platinum crucible, water poured on the mixture forms a deep orange-coloured solution. Muriatic acid being digested on the powder which remains, becomes first blue, then green, and at last deep red. By repeated fusions with potash, and digestions in muriatic acid, the whole of the black powder is decomposed and dissolved. The potash solution contains the metal called *osmium*, the muriatic acid solution the metal called *iridium*.

A piece of zinc being put into this last solution, precipitates a black powder, when heated it becomes white, and is *iridium*.

1. It has the appearance of platinum, and seems as difficult of fusion as that metal. It resists the action of acids, even the nitro-muriatic, almost completely.

2. Its affinity for oxygen seems weak; but, like other metallic bodies, it unites with that principle. The change of colour which its solution in muriatic acid assumes, seems to prove that it is incapable of combining with different dozes of oxygen. When the colour is *blue*, the metal seems oxydized to a minimum; when *red*, it seems oxydized to a maximum.

3. The simple combustibles do not seem to combine with iridium. Mr Tennant did to succeed in his attempt to unite it with sulphur.

4. It formed alloys with all the metals tried except arsenic. It does not alter the colour of gold, and cannot be separated from gold and silver by cupellation.

SECT. VIII. *Of Osmium.*

This metal was discovered by Mr Tennant at the same time with the preceding. It exists in the black powder separated during the solution of crude platina, and may be obtained in solution in potash, by the process described in the last section. When sulphuric acid is mixed with this solution, and the whole subjected to distillation, a colourless liquid comes over, consisting of water, holding the oxide of osmium in solution. It has a peculiar smell. Hence the name *osmium* applied to the metal. When mercury is agitated in this solution, the osmium combines with it, and leaves the water, and by applying heat, the mercury is driven off, and the metal obtained in a state of purity.

1. Osmium has a dark grey or blue colour, and the metallic lustre. In the open air it is easily dissipated by heat, but in close vessels it resists any degree of heat without alteration. It is not acted on by any acid, not even the nitro-muriatic, but is easily obtained in solution by the action of potash.

2. Osmium is easily oxidized by heat in the open air. The oxide has a peculiar smell, and a kind of oily appearance. It is volatile and soluble in water. The solution is colourless, does not alter vegetable blues, and strikes first a purple, then a blue, with the infusion of nut-galls.

3. The action of the simple combustibles on this metal is not yet known. Neither do we know much of its combination with other metals. It amalgamates with mercury, and Mr Tennant united it by fusion with copper and gold.

Sect. IX. *Of Copper.*

Copper seems to have been known as early as any metal except gold and silver. It was very much employed by the ancients before the method of manufacturing steel became familiar.

1. Copper has a fine red colour, but it soon tarnishes when exposed to the air. Its taste is styptic and nauseous, and when rubbed, it emits a disagreeable odour. It is very poisonous when taken internally. It is softer than iron, but harder than gold. Its specific gravity when pure is about 8·9. Its malleability and ductility are very considerable. A copper wire 0·078 inch in diameter is capable of support-

ing 302·2 lbs. avoirdupois without breaking. It melts at 27° Wedgewood, and gradually evaporates in visible fumes. When melted it has a bluish green colour, something like that of melted gold. When allowed to cool slowly, it crystallizes in quadrangular pyramids.

2. It is not altered though kept under water. When heated in contact with air, it is gradually converted into a black oxide by the combination of oxygen. Before a blowpipe of oxygen and hydrogen gases, it burns with a fine green flame. There are two oxides of copper. The protoxide is found naturally of a red colour, but when formed artificially it is orange. The peroxide is black.

The protoxide was first recognised by Mr Proust. It may be prepared by heating together a mixture of equal parts of black oxide and copper in powder in muriatic acid. Almost the whole is dissolved, and the solution is colourless. By pouring potash into the solution, the protoxide precipitates in the state of a yellow powder. This oxide is composed of 88·5 parts copper, and 11·5 oxygen. It attracts oxygen with such avidity, that it can scarcely be dried without becoming black.

The peroxide of copper is easily formed by keeping copper filings a sufficient time red hot. It contains 80 parts copper, and 20 oxygen. It is black. It combines with water, and forms a blue coloured matter called *hydrate of copper*.

3. Copper has not been combined with hydrogen or carbon; but it unites with sulphur and phosphorus forming the *sulphuret* and *phosphuret of copper*.

When equal parts of sulphur and copper are stratified in a crucible, they combine at a red heat, and form sulphuret of copper, of a very deep blue colour. It is brittle, and composed of 78 copper and 22 sulphur. If copper filings and sulphur in powder be mixed, and gradually heated in a flask, they combine before they are heated to redness; but at the instant of combination, a quantity of heat is evolved sufficient to convert the sulphuret into a glowing red, as if in a state of vivid combustion.

Sulphuret of copper is capable of combining with an additional dose of sulphur, and forming a *super-sulphuret*. It is brittle, has a yellow colour, and the metallic lustre. It is found native, and known under the name of *copper pyrites*.

Phosphuret of copper may be formed by projecting phosphorus on red hot copper. It is white, tough, but not ductile, hard, and contains the 5th of its weight of phosphorus. When repeatedly melted, it still retains about 1-12th of its weight of phosphorus, and then has much the appearance of steel, and admits of an equally fine polish.

4. Copper does not combine with the simple incombustibles. But muriatic acid oxydizes it, and combines with the oxide.

5. It combines with most of the metals, and some of its alloys are of considerable importance.

Copper unites readily with gold, and even heightens the colour, while it encreases the hardness, and does not injure the ductility. Gold coin consists of gold alloyed with copper or silver, or with both. Our coin contains 1-12th of alloy, usually both silver and copper. A pound of standard gold is coined into 44½ guineas.

Platinum combines with copper, but a violent heat is necessary. The alloy is white, hard, ductile, takes a fine polish, and is not liable to tarnish. Hence it has been proposed for the mirrors of telescopes.

Copper and silver easily unite by fusion. The alloy is harder and more sonorous than silver, and retains its white colour, even when the proportion of copper is considerable. Our silver coin consists of 12 1-3d silver, alloyed with one of copper. A pound of standard silver is coined into 62 shillings.

Copper may be united to mercury by pouring a small stream of it melted into mercury, heated nearly to the boiling point; or by keeping plates of copper in a solution of mercury in nitric acid. It is white, and at first soft, but gradually hardens when exposed to the air.

SECT. X. *Of Iron.*

Iron was not known at so early a period as gold, silver and copper. The art of working it was discovered in the east, and first communicated to the Greeks by the Phrygians, from whom it gradually made its way through the rest of Europe.

1. Iron has a bluish white colour, a styptic taste, and emits a smell when rubbed. It is one of the hardest of the metals. Its specific gravity varies from 7·6 to 7·8. It is attracted by the magnet or loadstone, and is itself the substance which constitutes the loadstone. When iron is perfectly pure, it retains the magnetic virtue but a short time.

It is malleable in every temperature, and its malleability increases with the temperature. It cannot be hammered into so thin plates as gold or silver. But it may be drawn out into very fine wire. An iron wire of 0·078 inch in diameter is capable of supporting 549.25 lbs.avoirdupois without breaking. When heated to 158° Wedgewood, it melts; a temperature so high, that it is difficult to go much beyond it.

2. It is much more easily converted into oxide than any of the metals described in the preceding sections. When left exposed to the air, especially in a moist place, it is soon converted to a red or yellow powder, called *rust*, which is nothing else than an *oxide* of iron usually combined with carbonic acid. When kept under water, especially in warm weather, it is gradually converted into a black brittle matter,

which is also an oxide, while some hydrogen gas is disengaged, owing to the decomposition of the water. If vapour of water be passed through red hot iron, the iron is rapidly oxidized and much hydrogen gas is obtained. If an iron wire, having a small bit of lighted cotton at its extremity, be plunged into a jar of oxygen gas, it burns with great brilliancy, and is converted into the same black oxide, which falls to the bottom of the jar in melted drops.

There are two oxides of iron which have been ascertained in a satisfactory manner, and I think that I have observed also a third. The *black* oxide may be obtained by keeping iron filings a sufficient time in water, by making steam pass through iron filings at a red heat, by burning iron wire in oxygen gas, or by dissolving iron in diluted sulphuric acid, and dropping potash into the solution. It is a black powder, insoluble in water, is attracted by the magnet, and has a good deal of metallic lustre. It is a compound of 73 parts iron and 27 oxygen.

The *red oxide*, or *peroxide*, may be obtained by keeping iron filings red hot in an open vessel and agitating them constantly till they are converted into a red powder; or by exposing a solution of iron in sulphuric acid for a long time to the atmosphere, and then precipitating by means of potash. It is a red powder, insoluble in water, and constitutes the base of several of the common red paints. Clay and bricks owe to it their yellow and red colours. It is composed of 52 iron and 48 oxygen.

Among the ores of iron there occurs one by no means uncommon, which seems to contain only one-half of the oxygen present in black oxide. It is black, has a good deal of metallic lustre, and is magnetic. This seems to be a peculiar oxide, and is probably the real *protoxide* of iron. Though, as my attempts to form it artificially did not succeed, there are still some doubts remaining about its reality.

3. Iron seems capable of combining with all the simple combustibles. Hydrogen, indeed, has never been united to it in a solid state, but hydrogen gas dissolves a little iron which it gradually deposites when kept over water.

Carburet of iron is found native, and is the substance mentioned in a preceding section under the name of *plumbago* or *black lead.* It is a soft substance, of a dark blue colour, a granular texture, and the metallic lustre. It does not burn with a flame, but gradually wastes away when kept red hot. When thrown into melted nitre a very splendid combustion is produced. Its nature was first developed by Dr Lewis, and afterwards more fully explained by Scheele and the French chemists. It seems to consist of about 19 parts of carbon and one part of iron.

Phosphuret of iron may be formed by dropping bits of phosphorus upon red hot iron. Its colour is dark steel-grey, it is very brittle, and does not easily dissolve in acids. It exists in different ores of iron, and is considered as giving to the variety of iron called *cold short iron*, the property of being brittle while cold, though it be malleable while hot. Phosphuret of iron was at first considered by Bergman as a peculiar metal and called *siderum.*

Sulphuret of iron may be formed by melting together in a crucible equal parts of iron filings and flowers of sulphur. It is of a black or very deep grey colour, brittle and very hard. When the two constituents of it combine, a great quantity of heat is evolved which makes the whole strongly red hot. This sulphuret is composed of 62·5 iron and 37·5 sulphur. It exists native, and is known by the name of *magnetic pyrites.* Its colour is that of bronze, it has the metallic lustre, but its powder is blackish grey. Its specific gravity is 4·518. It strikes fire with steel, and easily melts when heated. It is not only magnetic, but is itself capable of being converted into a permanent magnet, as Mr Hatchett discovered.

Iron is capable of combining with a still greater proportion of sulphur, and of forming a compound which may be called *super-sulphuret of iron.* It occurs native in great abundance, and is known by the name of *pyrites*, or *iron pyrites.* It is yellow, has the metallic lustre, is brittle, strikes fire with steel, and is often crystallized in cubes. Its specific gravity is 4·5. When distilled it loses its excess of sulphur, and is converted into common sulphuret of iron. By this process sulphur is sometimes obtained for the purposes of manufactures. Pyrites is composed of 80 common sulphuret of iron and 20 sulphur, or more exactly of about 47 iron and 53 sulphur. The super-sulphuret is not magnetic nor susceptible of becoming a magnet. Mr Hatchett found that phosphuret of iron is also capable of magnetic impregnation, and it is well known, that iron containing a portion of carbon or *steel*, possesses the same property in perfection. Hence Mr Hatchett concludes, that permanent magnets consist of iron combined with a certain proportion of a simple combustible. But, when saturated with simple combustibles, it loses its magnetic properties entirely. This is known with respect to iron saturated with sulphur and carbon, and is probable with respect to iron saturated with phosphorus. The subject requires and deserves farther investigation.

There are a great many varieties of iron which artists distinguish by different names; but they may be all reduced under the following classes: *Cast iron, wrought or soft iron,* and *steel.*

Cast-iron, or *pig-iron*, is the name of the metal when first extracted from its ores. The ores of iron commonly used are a mixture of the oxide of the metal and clay. They are reduced to small pieces and exposed to a violent heat mixed with charcoal and lime. The charcoal separates the oxygen, while the lime, combining with the clay, forms a liquid through which the melted iron falls and is collected at the bottom of the furnace. It is let out and cast in moulds. The cast iron thus obtained varies considerably according to circumstances. Three varieties have been well distinguished; namely, *white* cast iron, which is very hard and brittle; *grey* or *mottled*, which is softer and less brittle; and *black*, which is the softest and most fusible. Cast iron melts at 130° Wedgewood. Its specific gravity varies from 7·2 to 7·6. It contracts considerably when brought into fusion.

Cast iron is converted into *wrought* or *soft iron* by keeping it melted for a considerable time in a bed of charcoal and ashes and the *scoriæ* or *black oxide* of iron, and then forging it repeatedly till it becomes compact and malleable. In this state it is the substance described in the beginning of this section under the name of *iron*. It is considered when pure as a simple body; but it is difficult to procure it quite pure. It is almost always contaminated with some foreign body, either some of the other metals, or oxygen, carbon, or phosphorus.

When soft iron is kept red hot for some time in a bed of charcoal it is converted into *steel*. Steel is so hard as to be unmalleable while cold. It is brittle, resists the file, cuts glass, strikes fire with flint, and retains the magnetic virtue when impregnated with it. It is more sonorous and its specific gravity is greater than that of soft iron. It varies from 7·78 to 7·84.

These different states of iron have been long known, and many attempts were made to ascertain the cause of the differences among them. At last it was recognised by Bergman and the French chemists. Soft iron is the simple metal. *Steel* is iron combined with a portion of carbon, and has been for that reason called *subcarburet of iron*. The carbon, from Vauquelin's analysis, amounts to $\frac{1}{140}$th part of the whole. *Cast iron* is iron combined with a still greater proportion of carbon. It usually contains likewise a little oxygen.

4. Iron does not combine with azote, nor with muriatic acid. But that acid oxidizes iron and unites with its oxide.

5. Iron unites with most of the metals. Gold combines readily with iron, and forms a ductile alloy of a pale yellow or white colour according to the proportions. Platinum is found usually alloyed with iron, but it is difficult to combine the two metals artificially on account of the high temperature necessary to fuse them. Silver and iron combine and form a very hard alloy of a white colour. Mercury does not readily unite to iron, but an amalgam may be formed artificially. Iron may be united to copper by fusion, but not without considerable difficulty. The alloy is grey, imperfectly ductile, and very infusible. It is probable that the variety of iron called *hotshort*, because it is brittle when red hot, owes that property to the presence of a little copper with which it is alloyed.

SECT. XI. *Of Nickel.*

Nickel was first recognised as a peculiar metal in consequence of the experiments of Cronstedt in 1751. It is obtained from an ore which occurs in different German mines, and called *Kupfer nickel,* or false copper, because it resembles copper, though no copper can be extracted from it. It has been examined by many eminent chemists, especially by Richter, to whom we are indebted for the most exact account of its properties.

1. Nickel has a white colour like silver, it is softer than iron; its specific gravity, when hammered, is 8·666. It is malleable both cold and hot, and may be easily hammered out into thin plates. It is powerfully attracted by the mag-

net, and may be converted into a magnet precisely like bars of steel. It requires for fusion a temperature at least equal to 160° of Wedgewood. It is not altered by air nor water.

2. When moderately heated it tarnishes, and, if in powder, may be even converted into an oxide, but a strong heat reduces it again to the metallic state. We are at present acquainted with two oxides of nickel, the *green* and the *black.*

The protoxide may be obtained by dissolving nickel in nitric acid, precipitating the oxide by carbonate of potash, washing it and exposing it to a slight red heat. It is of a dark olive green, and is composed of 78 nickel and 22 oxygen. It is tasteless, soluble in acids, and the solution is grass-green. It dissolves likewise in ammonia.

The peroxide may be formed by mixing the protoxide with water, and passing a current of oxymuriatic acid gas through the liquid. A portion of the oxide dissolves and a portion acquires a black colour. When this black oxide is dissolved in acids, an effervescence takes place, owing to the escape of a portion of its oxygen.

3. Nickel has not been combined with hydrogen or carbon, but it unites readily with phosphorus and sulphur. Cronstedt formed sulphuret of nickel by fusion. The phosphuret may be obtained by dropping bits of phosphorus on red hot nickel.

4. Nickel does not unite with the simple incombustibles.

5. The alloys which it forms are but imperfectly known. They are mostly brittle and hard, and have been applied to no useful purpose.

SECT. XII. *Of Tin.*

Tin was known to the ancients, and was imported from Britain at a very early period by the Phenicians.

1. Tin has a fine white colour with a shade of blue. It has a slightly disagreeable taste, and emits a peculiar smell when rubbed. It is scarcely so hard as silver. Its specific gravity, when hammered, is 7·299. It is very malleable and may be hammered out into very thin plates. But its ductility and tenacity are much inferior. A tin wire $\frac{1}{12.6}$ inch in diameter is capable of supporting only 31 pounds without breaking. When tin is bent it produces a remarkable crackling noise. It melts at 442°, and when slowly cooled crystallizes in rhomboidal prisms.

2. Tin soon tarnishes when exposed to the air, but the tarnished coat is always extremely thin. It is not altered though kept under water. But, at a red heat it decomposes water, combines with its oxygen, and disengages the hydrogen. When kept melted it is soon covered with a greyish matter which becomes speedily yellow. But it is very difficult to oxydize tin completely by heat and air. Tin is capable of forming three different oxides.

The *protoxide* has not been obtained in a separate state; but Proust has shown that it exists in the compound called *Mosaic gold*, to be described immediately.

The *deutoxide*, or grey oxide, may be formed by dissolving tin in muriatic acid by means of heat, and adding potash in excess to the solution. A white powder falls, which is gradually converted into a grey matter, having a good deal of the metallic lustre. This is the grey oxide. It is tasteless readily soluble in acids, and greedily absorbs more oxygen. It is composed of four parts tin and one oxygen.

The peroxide may be obtained by heating tin in concentrated nitric acid. A violent effervescence ensues, and the tin is converted into a white powder, which is the peroxide. It dissolves readily in potash and in muriatic acid. It is composed of 72 parts tin and 28 oxygen.

3. Tin has not been combined with hydrogen or carbon, but it unites to phosphorus and sulphur.

Phosphuret of tin may be formed by throwing bits of phosphorus on melted tin. It has the colour of silver, is soft, may be cut with a knife, and extends under the hammer, but separates into laminæ. It is composed of 85 tin, and 15 phosphorus.

Sulphuret of tin may be formed by fusing the two ingredients together in a crucible. It is brittle, heavier than tin, and not so fusible. It is of a bluish colour, laminated texture, and capable of crystallizing. It contains 1-6th of sulphur, and 5-6ths tin.

When equal weights of peroxide of tin and sulphur are gradually heated in a retort, some sulphur and sulphurous acid are disengaged, and there is formed a substance called *Mosaic gold*, or *sulphureted oxide of tin*. It consists of gold coloured flakes, light, and adhering readily to the skin. Proust has shewn that this substance is a compound of sulphur and protoxide of gold. Neither nitric nor muriatic acid acts upon it, but it dissolves in hot nitro-muriatic acid, and is gradually changed into *sulphate of tin*. It dissolves in liquid potash when assisted by heat, and deflagrates when heated with twice its weight of nitre.

4. Tin does not unite with the simple combustibles, but it combines with the metals, and forms alloys, some of which are of considerable importance.

With gold it unites easily by fusion, and was thought formerly to render the metal very brittle; but the experiments of Alchorne, Hatchett, and Bingley, have shown that this opinion is to a considerable degree erroneous. Tin readily melts with platinum, and forms a brittle alloy, unless the proportion of platinum does not exceed 1-9th of the alloy. The alloy of tin and silver is very brittle and hard. Mercury dissolves tin with facility, and forms an amalgam capable of crystallizing. It is used for silvering the backs of looking-glasses.

Tin unites readily with copper, and forms an alloy known by the names of *gun-metal*, *bell-metal*, *bronze*, and *mirrors of telescopes*, according to the proportion of the ingredients. Tin diminishes the ductility of copper, and increases its hardness, tenacity, fusibility, and sonorousness. The specific gravity is greater than the mean, and is a maximum when the alloy is composed of 100 copper and 16 tin.

Bronze and gun metal are composed of 100 parts of copper, and from 8 to 12 of tin. Brass guns are made of it. The ancients used it for making cutting instruments. The χαλκὸς of the Greeks and the *æs* of the Romans was nothing else.

Bell-metal is usually composed of 3 parts of copper, and 1 of tin. It is greyish white, very hard, sonorous and elastic. The mirrors for telescopes consist of about 2 parts copper, and one tin. This alloy is very hard, the colour of steel, and admits of a fine polish.

When copper is used for culinary vessels, it is covered with a thin coating of tin, and is then known by the name of *tinned copper*. The coating of tin is extremely thin, but it completely prevents the copper from injuring the articles dressed in such vessels.

Tin does not unite readily with iron, but the two metals may be combined by fusing them together in a well closed crucible. The formation of *tin plate* shows the affinity between the two metals. This very useful compound is made by dipping clean plates of iron into melted tin.

SECT. XIII. *Of Lead.*

Lead was very well known to the ancients, but they do not always seem to distinguish it accurately from tin; though the properties of the two metals be exceedingly different.

1. Lead has a bluish white colour, and when newly melted, is very bright; but it soon tarnishes when exposed to the air. It is tasteless, but, when rubbed, emits a peculiar smell. It stains the fingers or paper dark blue. When taken internally, it is poisonous. It is very soft. Its specific gravity is 11·407. It is not encreased by hammering. It is very malleable; but its ductility and tenacity are not great. A lead wire $\frac{1}{12\cdot 6}$ inch in diameter, is capable of supporting only 18½ lbs. without breaking. It melts at 612°. When slowly cooled, it crystallizes in 4 sided pyramids.

2. Lead soon tarnishes in the open air, but the oxydizement never proceeds far. Water does not act upon it, though it greatly facilitates the action of the external air. Lead is believed at present to be capable of forming 4 different oxides.

The *yellow oxide* is the most important, as it constitutes the basis of almost all the known salts of lead. It may be obtained by dissolving lead in nitric acid, precipitating by carbonate of potash, and heating the white powder which falls almost to redness. It is yellow, tasteless, insoluble in water, but soluble in potash and in acids. It readily melts and forms a brittle semitransparent hard glass. It is composed of 100 lead, and 8 oxygen. It may be formed by exposing lead for a sufficient time to the action of heat and air, and is then known by the name of *massicot*.

If yellow oxide be dissolved in nitric acid, and the solution boiled over a quantity of lead filings in a phial, the liquid assumes a yellow colour, and yields yellow, brilliant crystals in scales. These crystals, according to Proust, consist of nitric acid, united an oxide of lead, containing less oxygen than yellow oxide. It must of course be considered as a *protoxide*. Upon examining this oxide, I found that it possessed the colour and properties of yellow oxide, and formed the same quantity of salt with nitric acid.

If massicot ground to a fine powder be exposed in a furnace to the flame of burning coals, playing upon its surface for about 48 hours, it is converted into a beautiful red powder called *minium*, or *red lead*. This is the *tritoxide* or *red oxide* of lead. It is of an orange red colour of the specific gravity of 8·940. Insoluble in water, but soluble in potash. When heated to redness, it gives out oxygen gas, and is partly reduced and partly melted, to a dark brown glass. It does not combine with acids. When acids dissolve it, they first reduce it to the state of yellow oxide. It is composed of 88 lead, and 12 oxygen.

If weak nitric acid be poured upon red lead, a portion is dissolved, but a portion remains in the state of a dark *brown powder*. This brown powder is the peroxide of lead. It is tasteless, light, and is not acted on by sulphuric or nitric acid. To muriatic acid it gives out oxygen, and converts it into oxymuriatic acid. It is composed of 80 lead and 20 oxygen.

When lead is first extracted from its ore, it almost always contains a portion of silver, which is always extracted when its quantity is sufficient to repay the expence. The process is known by the name of *refining* the lead. The lead is placed in a large flat dish called a *test*, composed of burnt bones and fern ashes, and exposed to the flame of a furnace. The lead gradually assumes a kind of vitriform state, and is either blown off or sinks into the test, while the silver remains unaltered. The lead by this process is converted into *litharge*. It consists of fine scales, partly red and partly yellow. It is yellow oxide combined with a small portion of carbonic acid.

3. Lead has not been combined with hydrogen or carbon, but it unites to phosphorus and sulphur.

Phosphuret of lead may be formed by dropping phosphorus into melted lead. It has a silver white colour with a shade of blue, and soon tarnishes.

Sulphuret of lead may be formed by mixing the two ingredients and melting them in a crucible. It occurs abundantly native, and is known by the name of *galena*. It is brittle, brilliant, of the colour of lead, less fusible, and usually crystallizes in cubes. Its specific gravity is about 7. It is composed of 86 lead, and 14 sulphur.

There is another sulphuret of lead, which I have occasionally found native also. The colour is lighter, and it burns with a blue flame when placed upon burning coals. It contains at least 25 per cent. of sulphur.

4. Lead does not combine with the simple incombustibles. It forms alloys with the other metals, but few of them are of much importance.

It renders gold as brittle as glass, when the proportion of it does not exceed $\frac{1}{1920}$th of the gold. It likewise renders platinum brittle. The alloy of silver and lead is very brittle, its specific gravity is greater than the mean. Mercury readily dissolves lead, and forms an amalgam capable of crystallizing. Copper dissolves in lead at a strong red heat. The alloy is grey and brittle, and when heated gradually, the lead melts and runs off, leaving the copper nearly pure. Iron unites with lead with difficulty, and the alloy is easily decomposed. Lead and tin may be combined in any proportion. The alloy is harder, and possesses more tenacity than tin.

SECT. XIV. *Of Zinc.*

The ancients do not appear to have been acquainted with this metal. It has been long known in China, and is mentioned by European writers in the 13th century. The method of extracting it from its ores was unknown in Europe till near the middle of the 18th century.

1. Zinc has a brilliant white colour, with a shade of blue, and is composed of thin plates cohering together. It has a

sensible taste, and acquires, when rubbed a slight smell. It is rather harder than silver. When hammered, its specific gravity is 7·1908. In its usual state it can scarcely be said to be malleable, but when heated a little above 212° it becomes very malleable, and may be rolled out into thin plates or drawn into wire. A zinc wire of 1-10th inch in diameter is capable of supporting about 26lbs. When heated to about 680°, it melts, aud, if cooled slowly, crystallizes in quadrangular prisms.

2. When exposed to the air, its surface is soon tarnished, but it hardly undergoes any other change. It is said to decompose water slowly, and to separate the hydrogen. At a red heat the decomposition goes on rapidly. When zinc is heated to redness, it takes fire, and burns with great brilliancy, being converted into a white oxide, which flies off in fine flakes like cotton. It was called *pompholyx*, *nihil album*, *lana philosophica*, *flowers of zinc*.

Two oxides of zinc are known. The *peroxide* is the white oxide obtained by the combustion of the metal. It is composed of 80 parts zinc, and 20 oxygen. It may be obtained likewise by dissolving zinc in sulphuric acid, and precipitating by means of potash. It is very white, light, and has some resemblance to chalk. It is tasteless and insoluble in water, and is not altered by exposure to the air.

The *protoxide* of zinc may be obtained by exposing the white oxide to a violent heat, or by digesting the solution of zinc in sulphuric acid with metallic zinc for some days. A flesh coloured substance precipitates, which is the oxide wanted. It is composed of 88 zinc, and 12 oxygen.

3. Most of the simple combustibles combine with zinc. Hydrogen gas procured by the action of diluted sulphuric acid on zinc, holds a little of the metal in solution, which it gradually deposites.

Carbon was considered as an occasional constituent of zinc, and to occasion the appearance of the black powder which separates when zinc is dissolved in sulphuric acid. But examining this powder, I found it a mixture of copper lead.

Phosphuret of zinc may be formed by dropping bits of ph phorus upon melted zinc. It has a considerable resembl to lead. It somewhat malleable.—Phosphorus combi likewise with the oxide of zinc.

Sulphuret of zinc exists native in considerable quanti and is known by the name of *blende*. It may be formed b fusing a mixture of sulphur and oxide of zinc.

4. Zinc does not unite with the simple incombustibl but it combines with the metals, and forms alloys, some which are of great importance.

It renders gold brittle, even when added in a very minut proportion. It melts readily with platinum, and renders i brittle. Silver readily combines with it, and forms a britt alloy. Mercury easily amalgamates in any proportion wh poured upon hot zinc. The amalgam is used to encrease th energy of electric machines.

Zinc combines with copper, and forms one of the most useful of all the alloys, namely *brass*. It is prepared by mixing oxide of zinc, charcoal powder, and granular copper, and heating them sufficiently in a crucible. Brass is yellow. The proportion of zinc which it contains varies somewhat. In some British manufactures it amounts to 1-3d.; while in Germany and Sweden it is said not to exceed 1-4th or 1-5th. Brass is much more fusible than copper. It is malleable while cold, but becomes brittle when heated. It is ductile, may be drawn into fine wire, and is much tougher than copper. When zinc in the metallic state is melted with copper, the alloy is known by the name of *pinchbeck*, *Prince's metal*, *Prince Rupert's metal*. The colour of pinchbeck approaches more nearly to that of gold, but it is more brittle than brass.

Zinc cannot easily be alloyed with iron. The alloy is hard and white and somewhat ductile. Tin and zinc easily unite. The alloy is hard and ductile. Lead and zinc may be united by fusion.

SECT. XV. *Of Bismuth.*

This metal was unknown to the ancients. It was well known in Germany at the beginning of the 16th century. But chemists were long in reckoning it a peculiar metal.

1. Bismuth is of a reddish white colour, and almost destitute of taste and smell. It is composed of broad brilliant plates adhering to one another. It is harder than silver. Its specific gravity is 9·822. When hammered cautiously its density is increased, but it breaks when struck smartly. It cannot be drawn out into wire. A rod of 1-10th inch diameter is capable of supporting about 29lbs. It melts at 476°, and may be distilled over in close vessels. When cooled slowly it crystallizes in parallelopipeds.

2. It tarnishes in the air, but is not altered when kept under water. When kept melted in an open vessel it is gradually converted into a yellow powder. In a strong red heat it takes fire and burns with a faint blue flame and emits a yellow smoke. This, when collected, is a *yellow oxide*. It is composed of about 89·3 bismuth and 10·7 oxygen. This is the only oxide of bismuth at present known. It is tasteless and insoluble in water. When heated it melts into a brown glass.

3. Bismuth has not been combined with hydrogen or carbon. It does not seem capable of combining in any notable proportion with phosphorus. But it unites very readily with sulphur by fusion. The sulphuret is bluish grey, very brittle and fusible, and crystallizes in four sided needles. It is composed of about 85 bismuth and 15 sulphur.

4. Bismuth does not unite with the simple incombustib but it combines with the metals, and forms alloys not hith to applied to any useful purpose. It renders gold, platin and silver brittle. It amalgamates readily with mercu When the mercury exceeds, the amalgam is fluid, and has t property of dissolving lead, and rendering it also fluid. B muth renders copper and iron brittle. It facilitates the f sion of tin and lead: a mixture of eight parts bismuth, f lead, and three tin is called fusible metal, because it melts 212°. Bismuth does not combine with zinc.

Secp. XVI. *Of Antimony.*

The ancients were acquainted with some of the ores of a timony, but it does not appear that they knew the metal i self. Who first extracted it from its ores is unknown. B the process is first described by Basil Valentine.

1. Antimony is of a greyish-white colour, and has considerable brilliancy. Its texture is laminated, and exhibits plates crossing each other in every direction. It is as hard as silver. Its specific gravity is 6·712. It is very brittle, and may be easily reduced to powder in a mortar. It melts at 810°, or when just red hot; and, when cooled slowly, forms oblong crystals perpendicular to the internal surface of the vessel in which it cools.

2. When exposed to the air it loses its lustre, but undergoes no other change. Neither is it altered by cold water, but at a red heat it decomposes water and combines with its oxygen, while hydrogen gas is emitted. When heated in an open vessel it gradually combines with oxygen, and evaporates in a white smoke, which, when collected, was formerly called *argentine flowers of antimony*. When suddenly heated antimony burns and is converted into the same white oxide. Two oxides of antimony are known.

The protoxide may be obtained thus. Dissolve antimony in muriatic acid, dilute the solution with water; a white powder falls, wash it and boil it in a solution of *carbonate of potash*. Then wash and dry it. The protoxide thus obtained is a dirty white powder. At a moderate red heat it melts and becomes opake, and crystallizes in needles on cooling. It is composed of 81·5 antimony, 18·5 oxygen.

The peroxide may be obtained by keeping the antimony in a red heat; for the argentine flowers are peroxide of antimony. It may be obtained also by dissolving antimony in nitric acid, or by throwing it into red hot nitre. It is white, insoluble in water, and less soluble in acids than protoxide. It is easily volatilized by heat, but requires a pretty high temperature for fusion. It is composed of 77 antimony and 23 oxygen.

3. Antimony has never been combined with hydrogen or carbon; but it unites readily to phosphorus and sulphur.

Phosphuret of antimony may be formed by dropping bits of phosphorus into melted antimony. It is white, brittle, and appears of a laminated structure.

Sulphuret of antimony exists native, and was formerly distinguished by the name of *antimony*, the pure metal being called *regulus of antimony*. It has a dark bluish grey colour and the metallic lustre. It is brittle and often crystallized. It is composed of 75 antimony and 25 sulphur.

The protoxide of antimony has the property of dissolving different portions of the sulphuret by means of heat, and forming with it a vitreous substance of a reddish brown colour, and differing in transparency according to the proportion of sulphuret. It is called *glass of antimony*, *crocus metallorum*, *liver of antimony*, according to its appearance.

4. Antimony does not combine with the simple incombustibles. But it forms alloys with almost all the metals. It renders other metals brittle, and none of its alloys is of

much consequence, except the alloy of tin and antimony which constitutes *pewter*, and of lead and antimony which constitutes the metal of printers types.

SECT. XVII. *Of Tellurium.*

This metal has been hitherto found only in the mine of Mariahilf in Transylvania. Its peculiar nature was first suspected by Muller of Reichenstein in 1782, and fully proved by the experiments of Klaproth in 1798.

1. Its colour is bluish white, its texture laminated, and its brilliancy considerable. It is very brittle. Its specific gravity is 6·115. It melts a little above the melting point of lead, and may be easily distilled over in close vessels. When cooled slowly it crystallizes.

2. When exposed to the blowpipe on charcoal it burns with a blue flame, and is converted into a white oxide which disperses in smoke. The same oxide may be obtained by dissolving the tellurium in muriatic acid and diluting with water. When heated it melts into a straw-coloured mass.

3. Tellurium may be combined with sulphur by fusion. The sulphuret has a leaden grey colour and radiated texture. The action of the other simple combustibles has not been tried.

4. It may be amalgamated with mercury, but we are ignorant of the metallic alloys which it is capable of forming.

SECT. XVIII. *Of Arsenic.*

The ancients gave the name of *arsenic* to a compound of arsenic and sulphur. The *white oxide of arsenic,* known in commerce by the name of arsenic, must also have been known to them. But they do not seem to have been acquainted with the substance which we call arsenic in its metallic state. The discoverer of this substance is unknown. But Brandt first ascertained its properties in 1733.

1. *Arsenic* has a bluish white colour, and a good deal of brilliancy. When heated in the open air, it blackens, smokes, and emits the odour of garlic. It is the softest metal known. Its specific gravity is 8·31. It is remarkably brittle. It is very volatile, subliming without melting when heated to 356°. When slowly sublimed it crystallizes in tretahedrons.

2. It may be kept under water without alteration, but in the open air, it soon falls into a black powder. We know two oxides which it is capable of forming.

The *white oxide* is obtained by exposing arsenic to a moderate heat. The metal takes fire, emits the smell of garlic, and is volatilized in a white smoke, which is the oxide in question. It is obtained in the large way during the smelting of various ores which contain arsenic. It is white, compact, and like glass. Its taste is acrid and sweet, and it is one of the most virulent poisons known. It dissolves in water, and exhibits different properties of an acid. It dissolves also in alcohol, and in oils. It crystallizes in tetrahedrons. It sublimes at the heat of 383°. Its specific gravity varies from 3·7 to 5·000 according to its state. It is composed of 75·2 arsenic and 24·8 oxygen.

The peroxide of arsenic was discovered by Scheele. It is usually called *arsenic acid*. It may be obtained by dissolving white oxide of arsenic in nitro-muriatic acid, evaporating to dryness, and applying sufficient heat to drive off these acids. In this state it is a white mass which readily dissolves in water. Its taste is excessively sour, and it possesses all the other properties of an acid. It is composed of 65·4 parts of arsenic, and 34·6 of oxygen.

2. Arsenic combines readily with the simple combustibles, carbon excepted, with which it has not hitherto been united.

When a mixture of tin and arsenic, or of zinc and arsenic is dissolved in muriatic acid, the hydrogen which exhales holds a considerable portion of arsenic in solution, and is known by the name of *arsenical hydrogen.* This gas possesses some curious properties, which have been investigated by Trommsdorff and Stromeyer.

Phosphuret of arsenic may be formed by mixing the two constituents, and distilling them together over a moderate fire. It is black and brilliant, and ought to be kept under water.

Sulphur combines readily with arsenic by heat. Two distinct compounds of these two bodies are found native. The first called *realgar* is of a scarlet colour, and often crystallizes in transparent prisms. It is tasteless, and not nearly so poisonous as arsenic. It is composed of 60 arsenic, and 30 sulphur. The second compound is called *orpiment.* It is of a fine yellow colour, and may be formed by pouring a solution of sulphureted hydrogen into arsenic dissolved in water. It is foliated, and much heavier than realgar. According to Thenard, it is composed of 3 sulphur and 4 arsenic.

3. Arsenic does not combine with the simple incombustibles, but it unites with the metals, and renders them brittle. None of its alloys have been applied to any useful purpose.

SECT. XIX. *Of Cobalt.*

Cobalt occurs in different mines in Germany and England, and has been long employed to give a blue colour to glass. Its peculiar properties were first ascertained by Brandt in 1733.

1. Cobalt has a grey colour with a shade of red, and is not very brilliant. It is of the hardness of silver, or a little harder. Its specific gravity is 7·7. It is brittle, and easily

reduced to powder. It melts at 130° Wedgewood, and crystallizes as it congeals. It is attracted by the magnet, and may itself be converted into a magnet.

2. It is not altered by air nor water at the ordinary temperature of the atmosphere, but in a red heat it is gradually converted into an oxide. We are acquainted with 3 oxides of cobalt.

The protoxide is blue. It may be obtained by dissolving cobalt in nitric acid, precipitating by potash, washing and drying the powder, and exposing it to a red heat for some time. It dissolves in acids without effervescence. It is composed of 83½ cobalt, and 16½ oxygen.

Moist protoxide, when exposed to the air gradually absorbs oxygen, and assumes an olive colour. This is the deutoxide of cobalt. When digested in muriatic acid, oxymuriatic acid flies off, and a solution of protoxide is obtained.

By gradual exposure to the air, more oxygen is absorbed, and the oxide becomes black. This is the peroxide. It forms abundance of oxymuriatic acid gas when digested in muriatic acid. It is composed of 80 cobalt and 20 oxygen.

3. Cobalt does not combine with carbon or hydrogen. Sulphuret of cobalt may be formed by melting the metal with sulphuret of potash. It is yellowish white, and is composed of 71½ cobalt and 28½ sulphur.

Phosphuret of cobalt may be formed by throwing bits of phosphorus upon red hot cobalt. It is white and brittle, and soon loses its metallic lustre.

4. Cobalt does not combine with the simple incombustibles. It unites with the different metals, and forms alloys which have been but imperfectly examined.

SECT. XX. *Of Manganese.*

Ores of the metal called manganese are common, in which it occurs always in the state of an oxide. Scheele, Bergman and

Gahn are the chemists to whom we are indebted for the first investigation of its properties.

1. Manganese has a greyish white colour, and considerable brilliancy. Its texture is granular. It is of the hardness of iron. It is brittle. Its specific gravity is 6·850. It requires a heat of 160° Wedgewood to melt it, and is therefore rather more infusible than iron.

2. It absorbs oxygen when exposed to the air. We are acquainted with 3 oxides of this metal.

The protoxide is white. It may be obtained by dissolving black oxide of manganese in nitric acid by the assistance of sugar, and precipitating by potash. It is a white powder composed of 80 manganese and 20 oxygen.

The deutoxide may be obtained by exposing the black oxide to a violent heat, or by dissolving black oxide in sulphuric acid, by means of heat, and precipitating with potash. It is a red powder composed of 74 manganese and 26 oxygen.

The peroxide or black oxide exists native in abundance. It has the metallic lustre, and is often crystallized. When heated, it gives out abundance of oxygen gas. It is composed of 60 manganese and 40 oxygen.

3. Manganese does not combine with hydrogen or carbon, but it unites with hydrogen and sulphur.

Phosphuret of manganese may be formed by dropping phosphorus on red hot manganese. It is white, brittle, granular, and disposed to crystallize.

Bergman did not succeed in his attempts to combine sulphur with manganese. But he formed a sulphurated oxide by heating 9 parts of black oxide, and 3 parts of sulphur.

4. Manganese does not combine with the simple incombustibles; but it unites with the metals, and forms alloys which have been but imperfectly examined.

SECT. XXI. *Of Chromium.*

This metal was discovered by Vauquelin, who extracted it from the red lead ore of Siberia. Owing to the violent heat necessary to fuse it, its properties are but imperfectly known.

1. Its colour is white, intermediate between that of tin and steel. Its specific gravity is 5·90. It is very brittle, assumes a good polish, and is magnetic, though inferior in this respect to iron, nickel and cobalt. Acids act upon it with great difficulty. It requires a very high temperature to melt it, so that hitherto it has only been obtained in small grains.

2. Chromium is not altered by exposure, but when heated in the open air, it is gradually oxidized. Three oxides of this metal are known.

The protoxide or green oxide may be obtained by exposing chromic acid to heat in close vessels. Oxygen is disengaged, and the green oxide remains behind.

The deutoxide is intermediate between the green oxide and chromic acid. Its colour is brown.

The peroxide or chromic acid is found native in *red lead ore.* It is of a red or orange colour, soluble in water, and composed of 1 part chromium, and 2 parts oxygen.

The remaining properties of chromium have not been examined.

SECT. XXII. *Of Uranium.*

This metal was discovered by Klaproth and extracted by him from an ore which occurs in Saxony, and is known by the name of *pechblende.*

1. It requires so violent a heat to melt it that hitherto the fusion has only been imperfectly accomplished. Its colour

is iron grey, it has considerable lustre, and is soft enough yield to the file. Its specific gravity is 9·000.

2. It forms various oxides which have been hitherto o examined by Bucholz.

When heated to redness it undergoes a species of comb tion, and is converted into a greyish black powder, which i the protoxide. It is composed of 95 uranium and five ox gen.

When uranium is dissolved in nitric acid and precipitat by potash, it is obtained in the state of a peroxide. It is yellow, tasteless powder, insoluble in water. It dissolves wi effervescence in muriatic acid, oxymuriatic acid gas bei exhaled It is composed of 80 metal, 20 oxygen.

Besides these two oxides, Bucholz is of opinion that the are several others intermediate between them, distinguish by their colour. He recognised four, namely, *the viol the greenish brown, the greyish green, and the orange.*

3. Uranium is capable of uniting with sulphur. No ex periments have been made of the action of the other simpl combustibles on it. Neither do we know the action of th simple incombustibles, or the alloys which it forms wit other metals.

Sect. XXIII. *Of Molybdenum.*

This metal is extracted from a scarce mineral called *molybdena*, first examined by Scheele. Molybdenum was first obtained in the metallic state by Hielm.

1. Hitherto it has only been obtained in small grains simply agglutinated. Its colour is silvery white. Its specific gravity is 8·611. It is brittle, not altered though kept under water, but the effect of air is unknown.

2. When heated in the open air it gradually combines with oxygen, and is volatilized in the form of small white needles. It seems capable of forming four different oxides.

The protoxide is brown. It is obtained by exposing molybdenum in powder to a red heat.

By exposing it to a longer and more violent heat it becomes *violet brown*. This Bucholz considers as a second oxide.

The *blue* oxide may be obtained by carrying the heat a little farther, or by triturating together one part of molybdenum and two parts of molybdic acid, boiling the mass in water and evaporating the liquid to dryness. This oxide possesses several properties of an acid. It converts vegetable blues to red, and combines with saline bases and forms salts. It may be called *molybdous acid*. It is composed of 100 metal and 34 oxygen.

The *white* oxide, or *molybdic acid*, is obtained by roasting molybdena for some time, dissolving the grey powder in ammonia, and pouring nitric acid into the solution. The oxide precipitates in fine white scales, which, when melted and sublimed, become yellow. It converts vegetable blues to red, but does not act so powerfully as the blue oxide. It is composed of two parts metal and one part oxygen.

3. Molybdenum combines with phosphorus and sulphur, but not with carbon and hydrogen.

Sulphuret of molybdenum occurs *native*, and is usually called *molybdena*. It is of a bluish grey colour, has the metallic lustre, and is composed of plates. It consists of 60 parts metal and 40 sulphur.

4. The simple incombustibles do not combine with molybdenum; but it unites with the metals and forms alloys which hitherto have been examined only by Hielm. None of them are of much importance.

SECT. XXIV. *Of Tungsten.*

Tungsten was discovered by Scheele, and reduced to the metallic state by the D'Elhuyars. It so difficult of fusion that, hitherto, it has been very seldom procured in a tolerably compact state. It is sometimes called scheelium after the discoverer.

1. It is of a greyish white colour, and has a good deal of brilliancy. It is very hard and seems to be brittle. Its specific gravity is 17·6. It requires a temperature at least equal to 170° Wedgewood to melt it. It is not magnetic.

2. When heated in an open vessel it is gradually oxidized. We are acquainted with two different oxides of this metal, the *blue* and the *yellow*.

The *protoxide* or *blue* oxide may be obtained by heating the yellow oxide for some hours in a covered crucible.

The *peroxide* or *yellow* oxide may be obtained by boiling tungsten or its ore in muriatic acid, decanting off the acid, and allowing it to settle. A yellow powder gradually precipitates. This yellow powder is to be dissolved in ammonia, the solution evaporated to dryness, and the residue kept for some time in a red heat. This yellow oxide is composed of 80 parts metal and 20 oxygen. It combines with bases, forms salts, and therefore has been considered as an acid. Its specific gravity is 6·12.

3. Tungsten combines with sulphur and phosphorus, but not with hydrogen or carbon.

4. The simple incombustibles do not unite with it, but it combines with the metals and forms alloys, hitherto examined only by the Elhuyarts.

SECT. XXV. *Of Titanium.*

This metal was discovered by Mr Gregor; but it received its name from Klaproth, who discovered it without any knowledge of the labours of Gregor.

1. It is so refractory that most persons have failed in their attempts to reduce it. Lampadius is said to have succeeded.

Its colour is that of copper, and it has considerable lustre. It is brittle but elastic.

2. It is easily oxidized by exposure to heat and air. We know three oxides of titanium, the *blue*, the *red*, and the *white*.

The protoxide, which is *blue* or *purple*, is formed by exposing titanium hot to the open air.

The red oxide is found native. It is often crystallized in four-sided prisms. Its specific gravity is 4·2, and it is hard enough to scratch glass. By a very violent heat it seems to be partially oxidized. It seems to be composed of 100 metal and 33 oxygen.

The *peroxide*, or white oxide, may be obtained by fusing the red oxide in a crucible with four times its weight of potash and dissolving the whole in water. A white powder gradually precipitates, which is the oxide in question. It is composed of about two parts metal and one oxygen.

3. Titanium has been combined with none of the simple combustibles except phosphorus. The phosphuret is of a white colour, brittle and granular, and does not melt before the blowpipe.

4. Hitherto titanium has been alloyed with none of the metals except iron.

SECT. XXVI. *Of Columbium.*

This metal was discovered by Mr Hatchett during the analysis of an ore from America, deposited in the British museum. He obtained from the mineral a white powder which possessed acid properties peculiar to itself. He shewed that this powder was a metallic oxide; but all attempts to reduce it to the metallic state were unsuccessful. We are at present ignorant of the properties of this metal.

Ekeberg, a Swedish chemist, announced, some years ago, that he had discovered a peculiar metal, to which he gave the name of tantalum. Dr Wollaston has lately proved that this new metal is the same with Mr Hatchett's columbium.

SECT. XXVII. *Of Cerium.*

This metal was discovered by Hisinger and Berzelius in a mineral found in a Swedish copper mine, and at first confounded with tungsten. To procure the oxide of cerium is easy, but all attempts to reduce that oxide to the metallic state have failed. The metal appears to be volatile, and is dissipated by a violent heat, while a moderate heat is not sufficient to reduce it.

1. Cerium appears to be white and brittle; but its other properties are unknown.

2. It forms, at least, two oxides, the *white* and the *brown;* and, according to the Swedish chemists, there are two oxides intermediate between these, the *yellow* and the *red.*

3. We are unacquainted with the effect of the simple combustibles and incombustibles on cerium. It has been alloyed with iron, but with no other metal.

SECT. XXVIII. *General Remarks.*

The following table exhibits a synoptical view of some of the principal properties of the metals.

als.	*Colour.*	*Hardness.*	*Specific gravity.*	*Melting point.*		*Tenacity.*
				Fahrenheit	*Wedgew.*	
	Yellow	6·5	19·361		32	150·07
n	White	8	23·000		170	274·31
	White	7	10·510		22	187·13
y	White	0	13·568	—39		
m	White	9	11·871		160+	
n	White		11·+		160+	
	White				160+	
	Blue				160+	
	Red	7·5	8·805		27	302·26
	Grey	9	7·8		158	549·25
	White	8·5	8·666		160+	
	White	6	7·299	442		31·00
	Blue	5·5	11·352	612		18·40
	White	6·5	6·861	680		18·20
	Reddish white	7·	9·822	476		20·10
ny	White	6·5	6·712	810		7·
m	White		6·115	612+		
	White	5	8·310	400+		

Table continued.

Metals.	*Colour.*	*Hardness.*	*Specific gravity.*	*Melting point.*	
				Fahrenheit	*Wedgew.*
Cobalt	Grey	6	7·7		130
Manganese	Grey	9	6·850		160
Chromium	White		5·90		170+
Uranium	Iron-grey		9·000		170+
Molybdenum	White		8·611		170+
Tungsten	White	9+	17·600		170+
Titanium	Red				170+
Columbium					170+
Cerium	White				170+

2. All the metals are capable of combining with oxy The knowledge of the number of oxides, and of the propo of oxygen which they contain, is of great importance. T following table exhibits a list of these oxides, as far as kno of their colours, and of the quantity of oxygen in each, co bined with 100 parts of metal.

Metals.	*Oxides.*	*Colours.*	*Oxygen.*
Gold	1	Purple	
	2	Yellow	32
Platinum	1	Green	7·5
	2	Brown	15
Silver	1	——	
	2	Olive	12·8
Mercury	1	Black	5
	2	Red	10
Palladium	1	Blue	
	2	Yellow	
Rhodium	P	Yellow	
Iridium	1	Blue?	
	2	Red?	
Osmium	P	Transpar.	
Copper	1	Red	13
	2	Black	25
Iron	1	Grey	18
	2	Black	37
	3	Red	92·3
Nickel	1	Green	28
	2	Black	
Tin	1	——	—
	2	Grey	25
	3	White	38·8
Lead	1	——	——
	2	Yellow	8
	3	Red	13·6
	4	Brown	25
Zinc	1	Yellow	13·6
	2	White	25·0
Bismuth	P	Yellow	12
Antimony	1	White	22·7
	2	White	30
Tellurium	P	White	
Arsenic	1	White	33
	2	Acid	53
Cobalt	1	Blue	19·7
	2	Green	
	3	Black	25
Mangenese	1	White	25
	2	Red	35
	3	Black	66·6
Chromium	1	Green	
	2	Brown	
	3	Red	200
Uranium	1	Black	5·17
	2	Yellow	28
Molybdenum	1	Brown	
	2	Violet	
	3	Blue	34
	4	White	50

Table continued.

Metals.	*Oxides.*	*Colours.*	*Oxygen.*	*Metals.*	*Oxides.*	*Colours.*	*Oxygen.*
Tungsten	1 2	Black Yellow	15 25	Columbium	P	White	
Titanium	1 2 3	Blue Red White	16 33 49	Cerium	1 2	White Red	

The Letter P in the second column signifies *Peroxide.*

3. Of the simple combustibles *carbon* has been only united hitherto to one metal, namely *iron:* hydrogen gas dissolves arsenic, zinc and iron, seemingly in the metallic state: phosphorus combines with most of the metals hitherto tried, but these compounds have been applied to no useful purpose: sulphur likewise combines with most metals; the sulphurets are often found native; some of them are prepared artificially as paints: we do not know the action of boracium on the metals.

4. The action of the simple incombustibles on metals is not striking. Azote has no effect. Muriatic acid oxydizes some of them, and it readily combines with the metallic oxides.

5. The combinations of the metals with each other called *alloys,* are some of them, as those of zinc and tin, of great importance. The greater number of them have only been very superficially examined.

DIVISION I.

OF UNCONFINEABLE BODIES.

The unconfineable bodies cannot be examined directly; because we have no method of retaining them till we ascertain their properties. We can only draw inferences respecting them by seeing the changes produced upon those bodies into which they enter, or from which they separate. They are four in number, namely, *light*, *heat*, *electricity* and *magnetism*. But the examination of the two last is not considered as the province of chemistry. The two first will occupy our attention in the following chapters.

CHAP. I.

OF LIGHT.

Every person is acquainted with the light of the sun, and of burning bodies, and that it is by means of light that bodies are rendered visible.

Huygens considered light as a subtile fluid filling space, and rendering bodies visible by the undulations into which it is thrown. While Newton and almost all other philosophers consider it as a subtile substance, constantly separating from luminous bodies, moving in straight lines, and rendering bodies visible by entering the eye.

Light takes about 8 minutes in moving across half the earth's orbit, which is a space exceeding 90 millions of miles; of course its velocity is not much less than 200,000 miles in a second. From this velocity, joined to the imperceptible effect produced by the impulse of the particles of light on

net, and may be converted into a magnet precisely like bars of steel. It requires for fusion a temperature at least equal to 160° of Wedgewood. It is not altered by air nor water.

2. When moderately heated it tarnishes, and, if in powder, may be even converted into an oxide, but a strong heat reduces it again to the metallic state. We are at present acquainted with two oxides of nickel, the *green* and the *black*.

The protoxide may be obtained by dissolving nickel in nitric acid, precipitating the oxide by carbonate of potash, washing it and exposing it to a slight red heat. It is of a dark olive green, and is composed of 78 nickel and 22 oxygen. It is tasteless, soluble in acids, and the solution is grass-green. It dissolves likewise in ammonia.

The peroxide may be formed by mixing the protoxide with water, and passing a current of oxymuriatic acid gas through the liquid. A portion of the oxide dissolves and a portion acquires a black colour. When this black oxide is dissolved in acids, an effervescence takes place, owing to the escape of a portion of its oxygen.

3. Nickel has not been combined with hydrogen or carbon, but it unites readily with phosphorus and sulphur. Cronstedt formed sulphuret of nickel by fusion. The phosphuret may be obtained by dropping bits of phosphorus on red hot nickel.

4. Nickel does not unite with the simple incombustibles.

5. The alloys which it forms are but imperfectly known. They are mostly brittle and hard, and have been applied to no useful purpose.

SECT. XII. *Of Tin.*

Tin was known to the ancients, and was imported from Britain at a very early period by the Phenicians.

1. Tin has a fine white colour with a shade of blue. It has a slightly disagreeable taste, and emits a peculiar smell when rubbed. It is scarcely so hard as silver. Its specific gravity, when hammered, is 7·299. It is very malleable and may be hammered out into very thin plates. But its ductility and tenacity are much inferior. A tin wire $\frac{1}{12.6}$ inch in diameter is capable of supporting only 31 pounds without breaking. When tin is bent it produces a remarkable crackling noise. It melts at 442°, and when slowly cooled crystallizes in rhomboidal prisms.

2. Tin soon tarnishes when exposed to the air, but the tarnished coat is always extremely thin. It is not altered though kept under water. But, at a red heat it decomposes water, combines with its oxygen, and disengages the hydrogen. When kept melted it is soon covered with a greyish matter which becomes speedily yellow. But it is very difficult to oxydize tin completely by heat and air. Tin is capable of forming three different oxides.

The *protoxide* has not been obtained in a separate state; but Proust has shown that it exists in the compound called *Mosaic gold*, to be described immediately.

The *deutoxide*, or grey oxide, may be formed by dissolving tin in muriatic acid by means of heat, and adding potash in excess to the solution. A white powder falls, which is gradually converted into a grey matter, having a good deal of the metallic lustre. This is the grey oxide. It is tasteless readily soluble in acids, and greedily absorbs more oxygen. It is composed of four parts tin and one oxygen.

The peroxide may be obtained by heating tin in concentrated nitric acid. A violent effervescence ensues, and the tin is converted into a white powder, which is the peroxide. It dissolves readily in potash and in muriatic acid. It is composed of 72 parts tin and 28 oxygen.

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When the experiment is made in the way above specified, the rise of the thermometer depends upon the distance of the canister from the mirror, being always the greater the nearer the canister is to the mirror. From Mr Leslie's experiments it follows, that the effect on the thermometer is very nearly inversely proportional to the distance of the canister from the reflector.

When the nature and position of the canister is the same, the rise of the thermometer is always proportional to the difference between the temperature of the hot canister and that of the surrounding air.

Heat radiates from the surfaces of hot bodies in all directions, but the radiation is most copious in the direction perpendicular to the surface of the hot body.

When different bodies are applied in succession to the surface of the canister, their power of radiation becomes evident by the effect they produce upon the thermometer. The following table exhibits this effect, as ascertained by the experiments of Mr Leslie.

Lamp-black, ...	100
Water, by estimate, ...	100+
Writing paper, ...	98
Rosin, ...	96
Sealing wax, ...	95
Crown glass, ...	90
China ink, ...	88
Ice, ...	85
Minium, ...	80
Isinglass, ...	80
Plumbago, ...	75
Tarnished lead, ...	45
Mercury, ...	20+
Clean lead, ...	19

Polished iron, ...	15
Tin-plate, ...	12
Gold, silver, copper, ...	12

Thus it appears that metals radiate heat worst, and that lamp-black, paper and glass are among the best radiators of it tried. The radiating power of the metals is increased by tarnishing and by scratching their surface.

The radiating powers of these bodies were ascertained by applying thin coats of them to the surface of the canisters. Now it appears that the radiating power increases somewhat with the thickness of the coat, till that coat amounts to the $\frac{1}{1000}$ of an inch, when it remains stationary. But this does not hold with respect to metallic bodies, the thinnest coat of which produces as great an effect as the thickest.

When the focal ball of the thermometer is glass, let us suppose that it rises 100° If we coat it with tin-foil, the rise will be reduced to 20°. Hence it follows that these bodies that radiate heat best imbibe it best, and that those which radiate worst imbibe worst.

The contrary holds with respect to reflectors, those substances reflect *best* which radiate *worst*, and *vice versa*. The following table exhibits the comparative goodness of different substances as reflectors, according to Mr Leslie's experiments.

Brass, ...	100
Silver, ...	90
Tin-foil, ...	85
Block-tin, ...	80
Steel, ...	70
Lead, ...	60
Tin-foil, softened by mercury, . .	10

Glass, ...	10
Ditto, coated with wax or oil, . .	5

When the polish of the reflector is destroyed by rubbing it with sand paper, the effect is very much diminished.

Radiation takes place only in elastic mediums. It is destroyed altogether by plunging the apparatus under water. It is nearly the same in air and in hydrogen gas, and does not seem to be affected by the nature of the elastic medium. It is diminished by rarifying the surrounding air.

When a substance is interposed between the hot canister and the reflector by way of screen, the effect is varied by its distance from the canister, by its thickness, and by the nature of its surface. The nearer it is to the canister the less is the radiation affected; at a certain distance all radiation is destroyed. The thinner the screen the less of the heat is interrupted; the radiation slowly diminishes as the thickness of the screen increases. When the surface of the screen radiates heat well, the radiation is much less interrupted than if it radiate heat ill. Thus, if the screen be glass, the thermometer still rises a certain number of degrees, but if it be tinfoil the thermometer does not rise at all. From these phenomena it cannot be doubted that the screen, in all cases, intercepts the whole of the heat, that it becomes hotter itself, and then radiates heat from its surface.

Such are the phenomena of the radiation of heat as far as they have been investigated. It follows very different laws from light in its radiation. Mr Leslie has endeavoured to show, that heat is not in reality radiated, but that it is propagated with the velocity of sound by means of undulations or pulses of air. This opinion he has supported with much ingenuity. But as he has brought no other evidence for its truth, but its convenience in explaining the phenomena, and as it is at variance with the direct experiments of other philosophers, it cannot be admitted till direct evidence be brought forward in support of it.

2. *Passage of Caloric through Bodies.*

Caloric we have seen is incapable of radiating through solid bodies, yet it is well known that all bodies are pervious to it. Through them, then, it must make its way in a different manner. In general it passes very slowly through them, and when it passes in this way, it is said to be *conducted* through them.

Bodies seem to conduct heat in consequence of their affinity for it, and of the property which they have of combining with an indefinite number of doses of it. Hence the reason of the slowness of the process. Hence also the reason why the temperature of the body through which it passes diminishes equally as we advance from the source of heat to the other extremity.

Bodies vary in their power of conducting heat. The metals are the best conductors of heat of all known bodies. From the experiments of Ingenhousz, it follows that silver and gold are the best conductors among the metals. Copper and tin follow next in order, and platinum, iron, steel and lead are nearly equal among themselves, but much inferior to the others. Stones came next after the metals, but they are greatly inferior to them. Bricks are still inferior to stones. Glass also is a bad conductor. Hence the facility with which it cracks when suddenly heated or cooled.

Dried woods are considerably inferior to glass. From the experiments of Meyer, it appears that they differ considerably among themselves. Charcoal is also a bad conductor. According to the experiments of Morveau its conducting power is to that of fine sand, as 2 to 3. Feathers, silk, wool and hair are still worse conductors than any of the preceding substances. Hence the reason that they answer so well as articles of clothing.

It is admitted on all hands, that all solid bodies are conductors, for they allow heat to pass through them. Liquids also allow heat to pass through them. But they differ from solids in the mobility of their particles. When a particle of a liquid is heated, it becomes specifically lighter, and therefore rises. Count Rumford has endeavoured to prove that heat passes through liquids only in consequence of the motion of their particles, and that if the particles of liquids were immoveable, heat could not pass through them at all. Hence he infers, that liquids are in reality non-conductors of caloric. But his experiments are not such as to warrant the conclusions he has drawn. The subject has been investigated by different chemists, with all the requisite care. It has been shown that heat can make its way downwards through liquids, in which case their particles cannot be supposed to move. Hence it follows that they are all conductors. They are however very bad conductors. Water, for example, conducts heat much worse than any of the dry woods.

The gases are still worse conductors than liquids. They differ a good deal among themselves in their conducting power. Hydrogen gas appears to be the best, and carbonic acid the worst conductor. From the experiments of Leslie, it appears that hydrogen conducts 4 times as well as common air. The conducting power of gases is diminished by rarefaction, by vapours of all kinds, and every thing which has a tendency to dilate air. The following table by Mr Dalton exhibiting the time taken by a thermometer to cool a given number of degrees in the different gases will give the reader some idea of their relative conducting powers.

Carbonic acid	112°
Sulphureted hydrogen Nitrous oxide Olefiant gas	100+
Common air Oxygen Azotic gas	100
Nitrous gas	90
Gas from pitcoal	70
Hydrogen gas	40

SECT. III. *Of the equal Distribution of Temperature.*

When substances of different temperatures are placed in each others neighbourhood, the hotter bodies become colder, and the colder acquire heat, and the changes continue till all the bodies acquire the same temperature. This property of caloric of distributing itself equally, has been called the *equilibrium of caloric*. It might with more propriety be called the *equal distribution of temperature*.

It had been taken for granted by Sir Isaac Newton, and was proved by the experiments of Kraft and Richmann, that when a body is suspended in a medium of a temperature different from its own, the difference between the temperature of the body and the medium diminishes in a geometrical ratio, while the time increases in an arithmetical ratio; or, which comes to the same thing, that in given small times, the heat lost is always proportional to the heat remaining in the body.

SECT. IV. *Of the Effects of Caloric.*

The changes which caloric produces on bodies may be arranged under 3 different heads; namely, 1. Changes in bulk; 2. Changes in state; and 3. Changes in combination.

1. *Changes in Bulk.*

Every addition or abstraction of heat produces a corresponding change in the bulk of the body affected. In general the *addition* of heat produces *expansion*, and the *abstraction* of it produces a *diminution* of bulk. To this general law there are perhaps one or two exceptions.

The expansion of gases by heat is greatest, that of liquids much smaller, and that of solids smallest of all. Thus 100 cubic inches of air by being heated from 32° to 212°, expand to 137·5 inches. The same augmentation of temperature makes 100 cubic inches of iron by the same increase of temperature expand only to 100·1 inches.

All gases undergo the same expansion by the same augmentation of temperature, and the same contraction by the same diminution of temperature. This change is nearly equable, though it is a little less at high temperatures than at low. From the most exact experiments hitherto made, we may conclude that air and all gases expand about $\frac{1}{481}$ part of their bulk for every degree of heat thrown into them.

From the experiments of Gay-Lussac, it appears that the steam of water and the vapour of ether undergo the same dilation as air when the same addition is made to their temperature. Hence it is reasonable to conclude, that all elastic fluids expand equally and uniformly by heat.

The expansion of liquids differs from that of elastic fluids, not only in quantity, but in the want of uniformity. Every liquid has a peculiar expansion of its own, different from that of every other liquid. The expansibility is greater when the temperature is high, than when it is low. Alcohol expands most of all the liquids hitherto tried. 100,000 parts of it at 32°, become 104,162 at 100°. Nitric acid is the next in order, then lintseed oil, then oil of turpentine, then sulphuric acid, then water, and mercury is the least expansible of all the liquids hitherto tried.

The solids expand much less than the liquids As far as observation has gone, their expansion is equable, or at least their deviation from it is insensible. 100,000 parts of glass at 32°, become at 100,083 at 212°. The order of the expansibility of the principal metals is as follows, beginning with the least expansible. Platinum, gold, antimony, cast-iron, steel, iron, bismuth, copper, brass, silver, brass-wire, tin, lead, zinc.

The property which bodies have of expanding when heat is applied to them, has suggested an instrument for measuring the relative temperatures of bodies. This instrument is the *thermometer*. A thermometer is a hollow tube of glass hermetically sealed and blown at one end into a hollow globe or *bulb*. The bulb and part of the tube are filled with mercury. When the bulb is plunged into a hot body, the mercury expands, and of course rises in the tube; when it is plunged into a cold body, the mercury contracts, and of consequence sinks in the tube. Thermometers are made in this way. The requisite quantity of mercury being introduced, the thermometer is plunged into melting snow, and the place where the mercury stands is marked. This is called the *freezing point*. The thermometer is then plunged into boiling water, and the point at which the mercury stands marked. This is called the *boiling water point*. The distance between these two points is divided into a number of equal parts called degrees, and these degrees are continued indefinitely above and below these two points.

The thermometer gets its name according to the number of degrees into which the space between the freezing and the boiling point is divided. There are four thermometers still used in Europe. In that of Reaumur the space between the two points is divided into 80°. The freezing point is marked 0, the boiling point 80°. In the thermometer of Celsius the same space is divided into 100 degrees. The freezing point is marked 0, the boiling point 100°. This is the thermometer used in Sweden and in France since the revolution. In the thermometer of Fahrenheit, the space between the two points is divided into 180 degrees. But the scale begins at the cold produced by a mixture of snow and salt, which is 32° below the freezing point. The freezing point is marked in consequence 32°, and the boiling point 212°. This is the thermometer used in Britain. It is the one always used in this work, except when some other is expressly mentioned. In the thermometer of Delisle, the space between the two points is divided into 150 degrees, but the graduation begins at the boiling point, which is marked 0. The freezing point is marked —150.

As mercury does not expand equably, the thermometer does not give us an exact measure of the increase of heat. Mr Dalton has endeavoured to prove that mercury expands as the square of the temperature, reckoning from its freezing point. This opinion has induced him to construct a new thermometer, graduated according to that principle. If this opinion be correct, the common degrees are too large near the bottom of the scale, and too small towards the upper part of it. 122°, or half way between freezing and boiling, corresponds according the new graduation with 110° of the old.

The exceptions to expansion by heat are of two kinds. 1. Those liquids which have a maximum of density corresponding with a certain temperature, and which of consequence expand whether they be heated or cooled beyond that temperature.

2. Certain liquids which become solid by cooling, and expand during the solidification.

Water is the only liquid at present known belonging to the first class. Its greatest density is at the temperature of 40°, or a little below it. If it be heated above that temperature. it expands, and it expands equally if it be cooled below it. A vast number of experiments have been made upon this point, and there appears no doubt of the matter of fact. Mr Dalton has lately endeavoured to show, that 36° is the degree at which the density of water is a maximum, and his observations appear satisfactory. No satisfactory explanation of the cause of this singular anomaly has yet been offered.

The second class of bodies is numerous. Water expands with great force when it freezes, and is converted into ice. The specific gravity of ice is at 0·92, that of water at 60° being 1·00. Hence ice is lighter than even boiling hot water. It always, therefore, swims on the surface of the water. A similar expansion is observable during the crystallization of most of the salts. Among the metals there are three which expand in the act of congealing; these are *cast-iron, bismuth*, and *antimony*. All the rest seem to contract instead of expanding. Sulphur appears also to expand when it congeals. This expansion in these bodies must be ascribed to a new arrangement which their integrant particles assume. It would lead one to suppose a kind of polarity in these integrant particles, otherwise it is difficult to conceive why they tend to expansion with so much force. Honey, oils, and most metals contract when they become solid. Sulphuric acid also appears to contract.

2. *Changes in the State of Bodies.*

All substances in nature, as far as we know them, occur in one or other of the three states, that of *solids*, of *liquids*, and of *elastic fluids*. In a vast number of cases, the same substance is capable of assuming each of these states in succession. Thus sulphur is usually solid, but at 218° it becomes a a liquid, and at 570° it boils, and is converted into an elastic fluid. Water is a liquid, but at 32° it freezes into a solid, and at 212° it boils into an elastic fluid.

All solids (a very few excepted) may be converted into liquids by heating them sufficiently, and almost all liquids by cooling them sufficiently, may be converted into solids. Liquids by heat may be converted into elastic fluids, and many elastic fluids may by cold be changed into liquids. The law then is, that solids by heat are converted into liquids and elastic fluids; while elastic fluids and liquids by cold are brought into the state of solids.

1. When solids are converted into liquids the change in some cases takes place at once, without any perceptible interval between solidity and liquidity. In other cases, the solid passes slowly through all the intermediate degrees of softness, till at last it becomes a complete liquid. The melting of ice is an example of the first kind, that of wax and tallow of the second. This change takes place at a particular temperature, which is easily ascertained in the first class, but not so easily in the second. If the substance at the usual temperature of the atmosphere be liquid, this point is called the *freezing point*; but if it be usually solid, it is called the *melting point*. Thus 32° is the *freezing point* of water, and 476° the *melting point* of bismuth.

Though 32° be the freezing point of water, it may be cooled down considerably below that point, without freezing. In thermometer tubes, I have cooled it down to 7°, and in a wine glass to 20°. When agitated or touched with a bit of ice, it freezes very suddenly.

The freezing point of water is lowered by dissolving different salts in it. Thus water saturated with common salt freezes at 4° with sal ammoniac at 8°, with Rochelle salt at 21°, and with nitre at 26°. When the proportion of the same salt dissolved in water is varied, it follows from the experiments of Sir Charles Blagden, that the freezing point is always proportional to the quantity of the salt.

The nitric and sulphuric acids vary remarkably in their freezing points, according to circumstances. When much diluted with water, the weakest part freezes, while a strong portion remains liquid. When very much diluted, the whole freezes, and the freezing point is lower according to the proportion of acid present. The strong acids themselves undergo congelation, and each has a particular strength at which its congelation is the easiest. If it be stronger or weaker, more cold is necessary to congeal it. Sulphuric acid of the specific gravity 1·780 freezes at 46°. But if it be diluted with a little water, it requires a cold of —45°, the strongest sulphuric acid freezes at 1°. The strongest nitric acid freezes at —45·5°. When considerably weaker it freezes at —2°, and when still weaker at —27·7°.

We are indebted to Dr Black for the first satisfactory explanation of the change of solids into liquids by heat. According to him, solids, in order to liquify, combine with a quantity of heat which enters into them, and remains in them without increasing their temperature. Hence he called it *latent heat*. Liquids congeal by giving out this *latent heat*. This opinion is established by simple but satisfactory experiments, and he ascertained that the latent heat of water is 140°. The following table exhibits the latent heat of some other liquids as ascertained by the experiments of Dr Irvine.

	Latent heat.	Ditto reduced to the specific heat of water.
Sulphur . .	143 68.	27 ·14
Spermaceti	145 . . .	
Lead	162 . . .	5·6
Bees wax. .	175 . . .	
Zinc	493 . . .	48·3
Tin	500 . . .	33
Bismuth . .	550 . . .	23·25

Dr Black has shewn also, that the softness of such bodies as are rendered plastic by heat, depends upon their combining with a quantity of caloric.

2. Thus the conversion of solids into liquids is owing to their combining with heat. There is another change no less remarkable to which bodies are liable when exposed to the action of heat. Almost all liquids, when exposed to a certain temperature, gradually assume the form of an elastic fluid, possessing the properties of air. These fluids retain their elastic form as long as the temperature continues, but when cooled down they lose that form, and are converted into liquids.

Some liquids are gradually converted into elastic fluids at all temperatures, while others do not begin to undergo the change till heated to a certain temperature. Water and alcohol are well known examples of the first class of liquids; sulphuric acid, and the fixed oils of the second. Water gradually evaporates even when in the state of ice, but sulphuric acid not till heated above 212°. The first class of liquids are said to *evaporate* spontaneously.

When other circumstances are the same, the evaporation increases with the temperature, and the elasticity of the vapour, of course, increases in the same proportion. At a certain temperature this elasticity balances the pressure of the atmosphere. When that happens, if the heat be applied below, the liquid assumes the aërial form with great rapidity. The vapour forces its way through the liquid, and a violent agitation is the consequence. The liquid is then said to *boil.* Every particular liquid has a certain temperature at which it begins to boil. Thus ether boils at 98°, alcohol at 174°, and water at 212°.

The boiling point varies with the pressure of the atmosphere. It is highest when the barometer is high, and lowest when it is low. All liquids boil in a vacuum about 145° lower than under the pressure of the atmosphere. The elasticity of vapour increases with the temperature. At 32° the vapour of water is capable of supporting a column of mercury 0·2 inches high, at 212° it supports a column of 30 inches.

Dr Black applied his theory of latent heat to the conversion of liquids into elastic fluids, and showed that it is owing to the very same cause as the conversion of solids into liquids, namely to the combination of a certain dose of caloric with the liquid without any increase of temperature. From his experiments, compared with those of Mr Watt and Mr Lavoisier, it appears that the latent heat of steam is about 1000°.

Thus, it appears that Dr Black's law is very general, and comprehends every change in the state of a body. It may be stated in its most general form as follows. *Whenever a body changes its state, it either combines with caloric or separates from caloric.*

3. It is probable that all elastic fluids, or gases, owe their elastic form, like steam, to the combined caloric which they contain; and that, if they could be subjected to a sufficient degree of cold, they would lose their elasticity and be con-

verted into liquids or solids. This has been done successfully to some gases; oxymuriatic acid and ammonia, for example, become liquid when cooled down low enough. The experiment has not succeeded with other gases, even though subjected at once to cold and pressure.

3. *Changes in Composition.*

Caloric not only increases the bulk of bodies and changes their state, but its action decomposes many compounds altogether, either into their elements, or it causes these elements to combine in a different manner. Thus ammonia, in a red heat, is resolved into hydrogen and azotic gases; and alcohol, by the same heat, is converted into inflammable air and water.

In general, those compounds, which have been formed by combustion, resist the action of heat with considerable obstinacy. Those that contain oxygen, and which have been formed without combustion are easily decomposed, and so are most of those that contain combustibles.

SECT. V. *Of the Quantity of Caloric in Bodies.*

This investigation naturally divides itself into two parts: 1. The *relative quantities* of heat in bodies, or the quantities in each necessary to produce a given change of temperature. This is usually termed *specific caloric*. 2. The *absolute quantity* of heat which exists in bodies.

1. *Of the Specific Caloric of Bodies.*

If equal weights of water and spermaceti oil be mixed at different temperatures, it is natural to expect that the mixture will acquire the mean temperature. Suppose the temperature of the water 100°, and that of the oil 50°, it is reasonable to expect that the water would be cooled down 25°, and that the oil would be heated 25°, and that the temperature after mixture would be 75°. But, if we make the experiment, we find the result very different. The temperature, after mixture, instead of 75° is 83°⅓, consequently the water has lost only 16⅔, while the oil has gained 33⅓. If we mix together equal weights of water at 50°, and spermaceti oil at 100°, the temperature, after agitation, will be only 66°⅓, so that the oil has lost 33⅓, while the water has only gained 16⅔. This experiment demonstrates that the same quantity of heat does not produce the same effect on water and spermaceti oil. The quantity which raises water 16⅔, raises the oil 33⅓, or it produces double the effect upon the oil that it does on the water. If other substances be tried in the same manner, we shall find that they all differ from each other in the quantity of caloric necessary to heat each of them a given number of degrees, some requiring more than the same weight of water would do, and others less. Now, the quantity necessary to produce this effect is called the *specific caloric* of each. The specific caloric of water is taken as the standard and called 1, and all the others referred to it. It is obvious, from the preceding example, that the specific caloric of water is double that of spermaceti oil. If we represent the first by 1, we must, of course, represent the second by 0·5.

This investigation was begun by Dr Black and prosecuted by Dr Irvine and Dr Crawford, who published a table of the specific heat of various bodies, and made it the foundation of his explanation of animal heat. Mr Wilke of Sweden likewise investigated the specific heat of various bodies. Lavoisier and Laplace attempted the investigation, by ascertaining how much ice given weights of bodies, heated a certain number of degrees, was capable of melting during the cooling. The subject was afterwards prosecuted by Kirwan, Meyer, Leslie and Dalton. The following table exhibits the result of all the experiments hitherto published on this important subject.

I. GASES.

		Sp. Caloric.
Hydrogen		21·4000*
Oxygen		4·7490*
Common air		1·7900*
Carbonic acid		1·0454*
Azote		0·7936*

II. WATER.

Ice		0·9000† 0·8000(*a*)
Water		1·0000
Steam		1·5500*

III. SALINE SOLUTIONS.

Carbonate of ammonia		1·851† 0·95 (D)
Sulphuret of ammonia	(0·818)	0·994†
Sulphate of magnesia Water	1 2	0·844 †
Common salt Water	1 8	0·832 †
Ditto	(1·197)	0·78(D)
Nitre Water	1 8	0·8167 ‡
Nitre Water	1 3	0·646 †
Carbonate of potash	(1·30)	0·75(D)
Muriate of ammonia Water	1 1·5	0·798 †
Tartar Water	1 237.3	0·765†
Sulphate of iron Water	1 2.5	0·734 †
Sulphate of soda Water	1 2·9	0·728 †
Alum Water	1 2·9	0·649 †
Nitric acid Lime	9⅓ 1	0·6189 ‡

		Sp. Caloric.
Ditto	(1·40)	0·62(D)
Solution of brown sugar		0·086 †
Ditto	(1·17)	0·77(D)

IV. ACIDS AND ALKALIES.

Vinegar		0·92 (D)
Nitric Acid	pale	0·844 †
	(1·20)	0·76(D)
	(1·2989)	0·6613 ‡ 0·62(L)
	(1·30)	0·66(D)
	(1·355)	0·576 †
	(1·36)	0·63(D)
Muriatic acid	(1·122)	0·680 †
	(1·153)	0·60(D)
Sulphuric acid	(1·885)	0·758 †
	(1·872)	0·429 † 0·34(L)
	(1·844)	0·35(D)
	(1·87)	0·3345‡
		0·333(*a*)
Do. 4, Water 5		0·6631 ‡
Do. 4, do. 3		0·6031 ‡
Do. equal bulks		0·52(D)
Acetic acid	(1·056)	0·66(D)
Potash	(1·346)	0·759 †
Ammonia	(0·997)	0·708 †
	(0·948)	1·03 (D)

V. INFLAMMABLE LIQUIDS.

Alcohol		0·930(*a*)
		0·6666 *
		0·64 (L)
		0·602 *
	(0·817)	0·70(D)
		1·086 †
	(0·848)	0·76(D)
Sulphuric ether	(0·76)	0·66 (D)
Oil of olives		0.718 † 0·50(L)

	Sp. Caloric.
Linseed oil	0·528 †
Spermaceti oil	0·5000 * 0·52 (D)
Oil of turpentine	0·472 † 0·400 (*a*)
Spermaceti	0·399 †
Ditto fluid	0·320 (*a*)

VI. ANIMAL FLUIDS.

Arterial blood	1·0300 *
Venous blood	0·8928 *
Cow's milk	0·9999 * 0·98 (D)

VII. ANIMAL SOLIDS.

Ox hide, with hair	0·7870*
Lungs of a sheep	0·7690*
Lean of ox-beef	0·7400*

VIII. VEGETABLE SUBSTANCES.

	Sp. Caloric.
Pinus sylvestris	0·65 ¶
Pinus abies	0·60 ¶
Tilea Europæa	0·62 ¶
Pinus picea	0·58 ¶
Pyrus malus	0·57 ¶
Betula alnus	0·53 ¶
Quercus robur sessilis	0·51 ¶
Fraxinus excelsior	0·51 ¶
Pyrus communis	0·50 ¶
Rice	0·5060 *
Horse beans	0·5020 *
Dust of the pine-tree	0·5000 *
Peas	0·4920 *
Fagus sylvatica	0·49 ¶
Carpinus betulus	0·48 ¶
Betula alba	0·48 ¶
Wheat	0·4770 *
Elm	0·47 ¶
Quercus robur pedunculata	0·45 ¶
Prunus domestica	0·44 ¶
Diospyrus ebenum	0·43 ¶
Barley	0·4210 *
Oats	0·4160 *
Pit-coal	0·28 (D) 0·2777 *
Charcoal	0·2631 *
Cinders	0·1923 *

IX. EARTHY BODIES, STONE-WARE AND GLASS.

Hydrate of lime	0·40 (D)
Chalk	0·27 (D) 0·256 *
Quick-lime	0·30 (D) 0·2229* 0·2168 ‡
Ashes of pit-coal	0·1855 *
Ashes of elm	0·1402 *
Agate	0·195 §
Stone-ware	0·195 †
Crown-glass	0·200(*a*)
Crystal	0·1929 ‡
Swedish glass	0·187 §
Flint-glass	0·19(D) 0·174 †

X. SULPHUR	0·19 (D) 0·183 †‖
Muriate of soda	0·23(D)

XI. METALS.

Platinum	0·13 (*a*)
Iron	0·143 (*a*) 0·13 (D) 0·125 † 0·1269 * 0·126 §
Brass	0·1123 * 0·116 § 0·11 (D)
Copper	0·1111 * 0·114 § 0·11 (D)
Sheet-iron	0·1099 ‡
Gun-metal	0·1100 ‖
Nickel	0·10(D)
Zinc	0·0943 * 0·102 § 0·10 (D)
Silver	0·082 § 0·08 (D)

	Sp. Caloric.
Tin	0·068 † 0·0704 * 0·07 (D) 0·060 §
Antimony	0·086 † 0·0645 * 0·063 § 0·06 (D)
Gold	0·050 § 0·05 (D)
Lead	0·050 † 0·0352 * 0·042 § 0·04 (D)
Bismuth	0·043 § 0·04 (D)
Mercury	0·033 † 0·0357 * 0·0290 ‡ 0·0496 (D)

XII. Oxides.

	Sp. Caloric.
Oxide of iron	0·320 ‡
Rust of iron	0·2500 *
Ditto, nearly free from air	0·1666 *
White oxide of antimony washed	0·220 † 0·2272 *
Do. nearly freed from air	0·1666 *
Oxide of copper ditto	0·2272 *
Oxide of lead and tin	0·102 †
Oxide of zinc ditto	0·1369 *
Oxide of tin nearly free from air	0·0990 * 0·096 †
Yellow oxide of lead do.	0·0680 * 0·068 †

* Crawford; † Kirwan; ‡ Lavoisier and Laplace; § Wilcke; ¶ Meyer; (L) Leslie; ‖ Count Rumford; (D) Dalton; (*a*) Irvine.

The specific heats of the gaseous bodies in the preceding table were ascertained by Dr Crawford by means of very delicate experiments, made with every possible precaution to insure accuracy. Yet there is little probability that they are accurate. Nor are we in possession of any means of making them more so by experiment. Mr Dalton has calculated the specific heat of the different gases from theory. The following are the numbers he obtained. The specific heat of water, as usual, being 1.

Hydrogen gas	9·382	Olefiant gas	1·555
Azotic	1·866	Nitric acid	0·491
Oxygen	1·333	Carbonic oxide	0·777
Air	1·759	Sulphureted hydrogen	0·583
Nitrous gas	0·777	Muriatic acid	0·424
Nitrous oxide	0·549	Aqueous vapour	1·166
Carbonic acid	0·491	Ether vapour	0·848
Ammonia	1·555	Alcohol vapour	0·586
Carbureted hydrogen	1·333		

Dr Crawford supposed, that the specific heat of bodies is permanent while they retain their state. But Mr Dalton has lately endeavoured to prove, that it increases with the temperature of all bodies.

Dr Irvine ascertained that the specific caloric always changes with the state of a body. When a solid becomes a liquid, or a liquid an elastic fluid, the specific caloric increases. When an elastic fluid becomes a liquid, or a liquid a solid, the specific heat diminishes.

The specific heat of bodies is increased by combining them with oxygen. Thus, the specific heat of metallic bodies is greater than that of metals and of acids than of their bases.

2. *Of the Absolute Quantity of Caloric in Bodies.*

As the same quantity of heat produces different changes of temperature in different bodies, it is obvious that the thermometer cannot indicate the absolute quantity of heat in bodies. Now, it becomes a question of considerable importance to enquire, if there be any method of ascertaining the absolute quantity of heat in bodies. Supposing a body deprived of all heat, and a thermometer applied to it, at what point would the thermometer stand?

Dr Irvine is the philosopher who first attempted to solve this problem. His reasoning was founded upon two suppositions. 1. That the specific heat was proportional to the absolute heat of bodies. 2. That the heat emitted or absorbed by a body, when it changes its state, is merely the consequence of the change which has taken place in its specific heat. Thus, when ice is converted into water, 140° of heat are absorbed; because the specific heat of water is so much greater than that of ice, that 140° are necessary to maintain the temperature. The first of these two suppositions gave him the ratio of the absolute quantity of heat in bodies, and the second the difference between two absolute calorics. Thus, if the specific heat of water be 10, and that of ice 9, then the absolute quantity of heat in water is, to that in ice, as 10 to 9. Call the absolute heat of ice x, then that of water is $x + 140$, and we have $x : x + 140 :: 9 : 10$. Hence we get this equation $10x = 9x + 1260$, which gives us $x = 1260$. Water at 32° of course contains 1400° of caloric. Dr Crawford, from his experiments, stated the real zero at 1500 below 0; and Mr Dalton places it at 6000 below 0.

Unfortunately, the truth of the two suppositions upon which this ingenious reasoning is founded, cannot be admitted. We have no proof that the specific heat of bodies is proportional to their absolute heat. The second supposition is at variance with the mechanical phenomena which present themselves when substances change their state, and would leave that change itself unaccounted for. It cannot therefore be admitted. Various other methods of ascertaining the absolute heat of bodies have been proposed. But, as they are all unsatisfactory, it is not necessary to detail them here.

SECT. VI. *Of the Sources of Caloric.*

The most important sources of heat are the five following, the *sun*, *combustion*, *percussion*, *friction*, and *mixture*.

1. *The Sun.*

The sun is an immense globe, the diameter of which is 888,246 miles. It was long supposed to be in a state of violent combustion. But the curious observations of Dr Herschel render it probable that this notion is erroneous. From them it appears, that the sun is an opaque globe, surrounded by an atmosphere of great density and extent. In this atmosphere there float two regions of clouds. The lowermost of the two is opake, and similar to the clouds which form in our own atmosphere; but the higher region of clouds is luminous, and emits the immense quantity of light to which the splendor of the sun is owing.

The sun emits three kinds of rays; the *calorific*, *colorific*, and *deoxidizing*. The first occasions *heat*, the second *colour*, and the third separates *oxygen* from various bodies.

When the solar rays strike transparent bodies, they produce very little effect; but opake bodies are heated by them. They pass through transparent bodies; but are retained, at least in part, by opake bodies. The deeper the colour of the opake body, the greater is the heat produced. Black bodies are most heated and white least, and the others in proportion to the intensity of the colour. The temperature produced in bodies by the direct action of the sun's rays seldom exceeds 120°. But when the heat is prevented from escaping, as, by enclosing a thermometer within a glass vessel whose bottom is cork, the temperature sometimes rises nearly to 240°. When the sun's rays are accumulated by means of burning glasses, the most intense heat is produced that it is possible to raise by any known method.

2. *Combustion.*

Few phenomena are more wonderful or interesting than *combustion*. When a stone or a brick is heated it undergoes no change; and, when left to itself, it soon cools again, and becomes as at first. But, when combustible bodies are heated to a certain degree in the open air, they suddenly become much hotter of themselves, continue for a certain time intensely hot, and send out a copious stream of light and heat. When this ceases, the combustible has undergone a most complete change, being converted into a substance possessed of very different properties, and no longer capable of combustion.

The first ingenious attempt to explain combustion was by Dr Hooke. According to him, there is an ingredient in air capable of dissolving combustibles when their temperature is sufficiently raised. The solution takes place with such rapidity that it occasions light and heat, which, in his opinion, were mere motions. The quantity of this solvent in air is not great. Hence the reason why so great a proportion of air is necessary to support combustion. This hypothesis was embraced by Mayow, but without making any great addition either to its evidence or probability.

Becher and Stahl soon after advanced another, which was much more universally embraced. According to them, all combustible substances contain in them a certain body called *phlogiston*, to which they owe their combustibility. This substance is the same in all combustible bodies. They owe their diversity to other ingredients combined with the phlogiston. During the combustion, the phlogiston separates, and the incombustible ingredients remain behind. The light and the heat are occasioned by the violent motion into which the phlogiston is thrown during its emission.

Light being considered as a body, occasioned a change in the Stahlian theory. Phlogiston was considered as nothing else than light fixed in bodies. When heat, in consequence chiefly of the discoveries of Dr Black, came to be considered as a body, the opinion respecting phlogiston got a new modification. It was considered as a subtile fluid, the same with the *ether* of Hooke and Newton, which occasioned gravity, and gave the bodies, called *heat* and *light*, the peculiar motions which produce in us the sensations of heat and light.

Dr Priestley first attempted to account for the necessity of air for combustion. Air, according to him, has an affinity for phlogiston, it draws it out of the combustible body and combines with it. But if so, whence come the heat and the light which make their appearance in all cases of combustion? According to Dr Crawford, they existed in the air, and were displaced by the phlogiston when it united with that fluid.

These modifications of the Stahlian theory were evidently improvements. But they left the nature of phlogiston altogether out of view. Kirwan first attempted to ascertain what this substance was, and to prove it the same with what is now called *hydrogen gas*. This opinion he supported in an ingenious Essay on *Phlogiston;* and it was embraced by many of the most respectable chemists in Europe.

Meanwhile, Mr Lavoisier had been investigating the subject with the minutest attention; and, after a very long, elaborate and ingenious examination, had satisfied himself that in every case of combustion, oxygen unites with the burning body. For a long time nobody would accede to his opinion. But at last, in 1785, Berthollet and Fourcroy joined him, and soon after Guyton-Morveau came over to his sentiments. They wrote a refutation of Mr Kirwan's essay, which was so satisfactory, that Mr Kirwan himself came over to their opinion. And after a short, but pretty violent controversy, the Lavoiserian theory of combustion was universally adopted. According to this theory, combustion consists of two processes, a *combination* and a *decomposition*. The oxygen of the air *combines* with the combustible, and gives out the *heat* and *light* with which it was previously *united*.

The following observations may, perhaps, contribute somewhat to elucidate what is still obscure in this curious process.

All bodies, as far as combustion is concerned, may be divided into *supporters, combustibles* and *incombustibles*. By supporters are meant certain bodies, not indeed capable of burning, but combustion cannot go on without their presence. *Air,* for example, is a supporter. *Combustibles* and *incombustibles* require no explanation.

Oxygen is the only simple supporter known. When it combines with an incombustible, it forms a compound supporter. The following are all the supporters at present known.

1. Oxygen.
2. Air.
3. Nitrous oxide.
4. Nitrous gas.
5. Nitric acid.
6. Oxymuriatic acid.
7. Hyper-oxymuriatic acid.

The combustibles are either the simple substances which have been already described, or combinations of these with each other, or with oxygen without combustion: in which last case, they may be called combustible oxides.

During combustion the oxygen of the supporter always combines with the combustible, and forms with it a new substance, which may be called a *product* of combustion. Now every product is either, 1. Water; 2. An acid; or, 3. A metallic oxide.

Some products are capable of combining with an additional dose of oxygen. But this combination is never attended with combustion, and the product, in consequence, is converted into a supporter. Such compounds may be called *partial supporters,* as a part only of the oxygen which they contain is capable of supporting combustion.

Since oxygen is capable of supporting combustion only in the supporters and partial supporters, it is clear that it is in a different state in these bodies from what it is in products. It is probable that, in supporters it contains, combined with it, a considerable quantity of heat, which is wanting in products.

It is probable that combustible bodies contain light as a constituent. For the quantity of light emitted during combustion depends upon the combustible; while the heat seems, in some measure at least, to depend upon the oxygen. If these two suppositions be admitted, the phenomena of combustion admit of an easy explanation. The base of the oxygen and of the combustible combine together and form the product, while the heat of the one and the light of the other in like manner unite and fly off in the form of fire.

3. *Percussion.*

It is well known that heat is produced by the percussion of hard bodies against each other. Iron may be heated red hot by striking it with a hammer, and the sparks emitted by flint and steel are well known.

This evolution of heat appears to be the consequence of the permanent or temporary condensation of the bodies struck. Iron and most metals become specifically heavier when hammered. Now condensation always evolves heat. When air is condensed it gives out a considerable quantity of heat sufficient to set fire to tinder. When muriatic acid gas is passed through water, it is condensed, and the water becomes hot. On the other hand, when air is rarified, it becomes suddenly much colder.

It is not difficult to see why condensation evolves heat. The particles being forced nearer each other, the repulsive force of the heat is increased, and a portion in consequence is driven off. The specific caloric of bodies is diminished by condensation. Now the specific caloric can scarcely be conceived to diminish without the body giving out heat.

A part of the heat which follows percussion, is often owing to another cause. By the percussion, the heat of the body is raised so high that combustion commences, and this occasions a still farther increase of the heat. It is in this way that sparks are produced when flint and steel are struck. The sparks are small pieces of the steel which have taken fire and melted during their passage through the air.

4. *Friction.*

Heat is not only evolved by percussion, but also by friction. And not only by the friction of hard bodies but even of soft bodies, as when the hand is rubbed against the slieve of the coat. No heat has ever been observed from the friction of liquids.

The heat evolved by friction seems to be owing to the same cause as that by percussion; namely, a condensation of the substances rubbed. This condensation is, in some cases, permanent; but, when the bodies rubbed are soft, it can only be momentary.

The heat evolved by friction is sometimes very considerable. Thus Count Rumford boiled water by the heat evolved by rubbing a steel borer against a cylinder of gun-metal. Probably in this case the density of the metal was a little increased. A very small increase would account for the whole heat evolved.

5. *Mixture.*

In a great number of cases a change of temperature takes place when bodies combine chemically with each other. Sometimes the compound becomes colder than before, and sometimes hotter.

When glauber's salt in crystals pounded is dissolved in water, a considerable degree of cold is produced, and the cold is still more intense if the salt be dissolved in muriatic acid. If muriate of lime in powder and dry snow be mixed together, so great a degree of cold is produced that mercury may be frozen if it be surrounded by such a mixture. Potash and snow produce an equally great cold. When nitric acid or sulphuric acid is poured upon snow, the snow dissolves and an intense cold is produced.

On the other hand, when sulphuric acid and water are mixed, so great a heat is evolved, that the liquid is considerably hotter than boiling water. Heat also is produced when nitric acid and water, or water and alcohol are mixed together. Heat also is produced if glauber salt, in a state of efflorescence, is dissolved in water. An intense heat is produced by dissolving quick-lime in snlphuric acid.

In most of these cases of change of temperature, water is either one of the substances combined, or it forms an essential constituent of one of them. The heat or the cold produced depends often on this constituent. Thus Glauber's salt, containing its water of crystallization, produces cold when dissolved; while the same salt, deprived of its water of crystallization, produces heat.

If the new compound be more fluid than the two constituents of it, the temperature sinks; if it be less fluid, the temperature rises. Thus, when snow and common salt are mixed, they gradually melt and assume the form of a liquid, and the temperature sinks to zero. Solid water cannot become liquid without combining with a quantity of heat, and the same rule applies to all solid bodies which become liquid. Hence the cold evolved in these cases. The water of crystallization in Glauber's salt is solid: it becomes liquid when the salt is dissolved. Hence the cold produced. When the same salt, free from its water of crystallization, is thrown into water, it first combines with a portion of the water and renders it solid. Hence the heat evolved. Dr Black's doctrine of latent heat affords a satisfactory explanation of these phenomena.

When the density of two liquids united is greater than the mean, heat is evolved, because the specific caloric of the new compound is less than that of the constituents. This was first observed by Dr Irvine, and it accounts for the heat evolved when water is mixed with sulphuric acid, nitric acid or alcohol.

Thus it appears that the changes of temperature produced by mixture, are either occasioned by the change of state which the water undergoes, or by a diminution of specific caloric, in consequence of the new combination.

BOOK II.

OF COMPOUND BODIES.

Compound bodies are substances composed of two or more simple substances united together. They amount to several thousands; but the present state of the science does not permit us to give an account of them all under their proper heads.

Compound bodies are of two kinds. Some are formed by the combination of two or more simple substances with each other, while others are formed by the union of two or more compound bodies with each other. To the first class belong *phosphoric acid*, composed of phosphorus and oxygen; and *ammonia*, composed of azote and hydrogen. To the second class belong *phosphate of ammonia,* composed of phosphoric acid and ammonia.

Besides the 35 simple substances described in the preceding pages, there are a number of others brought into view by the sagacity of Mr Davy. They constitute the bases of the substances called *alkalies* and *earths,* which form a distinct order by themselves, and may be called *salifiable bases.* This book shall be divided into three parts. I. *Salifiable Bases.* II. *Primary Compounds.* III. *Secondary Compounds.* And we shall terminate it by an account of those animal and vegetable snbstances not yet sufficiently known to admit of their being arranged under either of the preceding heads.

DIVISION I.

OF SALIFIABLE BASES.

The salifiable bases may be arranged under the four following heads:

1. Volatile alkalies.
2. Fixed alkalies.
3. Alkaline earths.
4. Earths proper.

CHAP. I.

OF VOLATILE ALKALIES.

The term alkali was introduced into chemistry after having been applied to a plant that still retains the name of *kali.* When this plant is burnt, the ashes washed in water, and the water evaporated to dryness, a white substance remains, called *alkali*. Alkali may be obtained from many other bodies besides this plant. Chemists gradually discovered that different substances had been confounded together under the name of alkali. The word, in consequence, became general, and is now applied to all substances having the following properties.

1. A caustic taste.
2. Volatilized by heat.
3. Capable of combining with acids and of destroying their acidity.
4. Soluble in water, even when combined with carbonic acid.
5. Capable of converting vegetable blues to green.

The alkalies at present known are three in number: 1. Ammonia; 2. Potash; 3. Soda. The first is called *volatile alkali*; the two last *fixed alkalies*.

SECT. I. *Of Ammonia.*

Put into a retort a mixture of three parts quick-lime and one part sal ammoniac, plunge the beak of the retort into a trough filled with mercury. Apply heat. A gas comes over which may be received in glass jars filled with mercury. This gas is *ammonia*.

This gas possesses the mechanical properties of common air. Its taste is acrid and pungent, and it has a strong smell, not unpleasant when diluted. Animals cannot breathe it, and combustibles do not burn in it. Its specific gravity is 0·600, that of air being 1·000. At the temperature of 60°, 100 cubic inches of it weigh 18·16 grains. When exposed to a cold of —45°, it is condensed into a liquid. When passed through a red hot tube, it is decomposed and converted into hydrogen and azotic gases.

Water absorbs it with great rapidity. This liquid absorbs 780 times its bulk of this gas, and six parts of water, by this absorption, increase in bulk to 10 parts. The specific gravity of this solution is 0·900. It is in this state that ammonia is commonly used. It was known to the alchymists, and called *hartshorn, spirit of urine,* and *spirit of sal ammoniac.*

Ammoniacal gas is not altered by light, but when electric sparks are made to pass through it, its bulk is nearly doubled, and it is converted into hydrogen and azotic gases. Hence it follows that it is composed of hydrogen and azote. The most exact experiments make the proportion of the constituents three parts in bulk of hydrogen gas and one part of azote, or in weight

81·5 azote.
18·5 hydrogen.

100·0

When mixed with oxygen gas, it detonates by electricity, and is decomposed as Dr Henry has ascertained. To analyse ammonia by means of oxygen, it ought to be first mixed with half its bulk of oxygen gas. An electric spark occasions a combustion, but the whole of the hydrogen is not consumed. By adding another quantity of oxygen gas a new combustion may be produced. Double the oxygen gas consumed indicates the bulk of hydrogen, and the azote remaining in the residuary gas its bulk may be estimated.

Sulphur is the only one of the simple combustibles that combines with ammonia. The combination may be produced by mixing it with sulphur in the state of vapour, or better by distilling a mixture of equal weights of sal ammoniac, sulphur and quick-lime diluted with a little water. A yellow liquid comes over which consists of water, holding in solution ammonia and sulphur. It contains an excess of ammonia.

When ammonia comes in contact with phosphorus at a red heat it is decomposed, and phosphureted hydrogen gas formed. When ammoniacal gas is made to pass through red hot charcoal, a substance is formed called *prussic acid.*

Ammonia is not acted on by azote, but it combines with muriatic acid and forms the well known salt called *sal ammoniac*, or *muriate of ammonia.*

Ammonia is capable of oxidizing some of the metals, and of dissolving the oxides formed. Liquid ammonia dissolves the oxides of silver, copper, iron, tin, nickel, zinc, bismuth and cobalt. When digested upon the oxides of mercury, lead or manganese, it is decomposed, water formed and azotic gas emitted. It combines readily with the peroxides of gold and silver, and forms two remarkable compounds known by the names of *fulminating gold* and *silver.*

Fulminating gold may be obtained by dissolving gold in aqua regia, and precipitating it by ammonia. A yellow precipitate falls which is to be washed and dried. It is fulminating gold. It is composed of five parts yellow oxide of gold, and one part of ammonia. It fulminates violently when heated to the temperature of about 300° or 400°, also when struck violently with a hammer, or when triturated in a mortar. Water is formed and azotic gas emitted.

Fulminating silver was discovered by Berthollet. It may be prepared by dissolving silver in nitric acid, precipitating by lime-water, drying the precipitate in a filter, and then keeping it for twelve hours in liquid ammonia. Its tendency to explode is so strong, that it is dangerous to prepare it except in small quantities.

If a globule of mercury be put into a hollow in a moistened piece of sal ammoniac, and exposed to the energy of a powerful galvanic battery, it increases in bulk and acquires the consistency of butter. Its specific gravity is reduced to 3. The mercury has obviously amalgamated with some metallic body. If this amalgam be thrown into water, the mercury resumes its original state, a little hydrogen gas is exhaled, and the water is impregnated with a weak solution of ammonia. Hence it would appear that the amalgamating metal is the basis of ammonia; that it decomposes water, emits the hydrogen, and retains the oxygen; and that, by this combination, it is converted into ammonia. This unknown metallic basis of ammonia has been called *ammonium*. It follows, from the preceding experiment, that ammonia contains oxygen. Yet its presence cannot be detected by experiment. It is said that Mr Davy has lately got over this apparent inconsistency, by ascertaining that *azote* is a compound of oxygen and hydrogen. If so, hydrogen in its pure state is a metal.

CHAP. II.

OF FIXED ALKALIES.

The fixed alkalies are not gaseous. They may be exhibited pure in a solid state. Two fixed alkalies only are at present known; namely, *potash* and *soda*.

SECT. I. *Of Potash.*

Potash, called also *vegetable alkali*, is obtained from the ashes of trees and of vegetables that grow at a distance from the sea-shore. These ashes are lixiviated with water, the water evaporated to dryness; the residual salt mixed with twice its weight of quick-lime, and a sufficient quantity of water to make the whole into a thin paste. The water is drawn off in 24 hours, boiled to dryness in a clean iron pot, and then mixed with a quantity of alcohol equal in weight to half the original salt. The alcoholic solution, after standing some days in well closed phials, is decanted off, and the alcohol distilled away in a silver still. The substance which remains behind is pure potash.

Potash is a brittle substance of a white colour, and a smell like that which is perceived during the slacking of quick-lime. Its taste is extremely acrid and it is very corrosive, destroying the texture of most animal and vegetable bodies to which it is applied. Its specific gravity is 1·7085.

When heated it melts. At a red heat it evaporates in a white acrid smoke.

It contains about one-fourth of its weight of water, even after being exposed to a red heat. When exposed to the air it speedily absorbs moisture and runs into a liquid. At the same time it combines with carbonic acid, for which it has a strong affinity.

Water dissolves twice its weight of potash. The solution is limpid and colourless, and almost of the consistency of an oil. It is in this state that potash is commonly used by chemists. When evaporated to the proper consistency, the potash crystallizes.

2. Potash does not combine with oxygen, nor with any of the simple combustibles except sulphur. The combination takes place by simple trituration of the two substances in a mortar, or by fusing them in a crucible. This compound is called *sulphuret of potash*. It was formerly distinguished by the name of *hepar sulphuris*, or *liver of sulphur*. Its colour is brown; it is hard, brittle, and has a glassy fracture. Its taste is acrid and bitter, and it leaves a brown stain on the skin. It converts vegetable blues to green and soon destroys them. When exposed to the air it acquires a green colour and emits the smell of sulphureted hydrogen. In this state it is a triple compound, being composed of sulphur, potash and sulphureted hydrogen. The last ingredient is formed by

the decomposition of the water absorbed from the atmosphere. It dissolves in water and forms a greenish yellow solution. In this state it is called *hydrogureted sulphuret of potash*.

When liquid potash and phosphorus are heated in a retort, water is decomposed and *phosphureted hydrogen* gas is formed and comes over. This gas possesses the curious property of taking fire when it comes in contact with the air.

3. Potash does not unite with azote; but it combines with muriatic acid, and forms the salt called *muriate of potash*.

4. Several of the metals, when kept in liquid potash, are oxidized, water being decomposed. This is the case with iron, zinc and molybdenum, and probably also with tin and manganese.

Potash dissolves the oxides of lead, tin, nickel, arsenic, cobalt, manganese, zinc, antimony, tellurium, tungsten, molybdenum.

Mr Davy has lately succeeded in decomposing potash, and in showing that it is a compound of oxygen and a peculiar metal, to which he has given the name of *potassium*. The decomposition was accomplished by exposing potash to the action of the galvanic battery. The metallic base separated at the negative extremity while oxygen was evolved at the other. More lately, Thenard and Gay-Lussac have ascertained that potash is decomposed and potassium obtained when it is made to come in contact with iron turnings heated to whiteness in a gun-barrel.

Potassium, the base of potash, possesses the following properties. It is white like mercury. At 50°, it is a soft malleable solid, which becomes imperfectly liquid at 60°, and perfectly so at 100°. While at 32°, it is hard, brittle and crystallized in facets. It is not only lighter than water, but lighter than any known liquid. Its specific gravity does not exceed 0·6. Its affinity for oxygen is very great. In the open air it is covered with a crust of potash in a few minutes. When thrown upon water it decomposes that liquid with rapidity, hydrogen gas holding potassium in solution is disengaged and takes fire, which occasions the combustion of the whole potassium.

When heated in a small quantity of oxygen gas it loses its metallic appearance and assumes a reddish brown colour. In this state it may be considered as a protoxide of potassium.

Oxymuriatic acid sets potassium on fire and converts it into muriate of potash.

It combines with phosphorus and forms a phosphuret which has the colour of lead, and remains solid at a heat little short of that of boiling water. In the open air it burns and is converted into phosphate of potash.

It combines rapidly with sulphur by heat, and heat and light are emitted at the moment of combination. The sulphuret has a grey colour, and, in the open air, is soon converted into sulphate of potash.

It combines and forms alloys with all the metals tried, but these alloys are soon destroyed in the open air or in water, and the potassium converted in potash.

Potash, according to the experiments of Mr Davy, is composed of about 86 potassium.

14 oxygen.

100

Sect. II. *Of Soda.*

Soda, called also *fossil* or *mineral alkali*, is found in large quantities ready formed in the earth. It may be obtained also from the ashes of the different species of *salsola* and other marine plants. The process is the same as that for procuring potash.

When pure it has a very strong resemblance to potash in most of its properties.

Its colour is greyish white, and it agrees with potash in its taste, smell and action on animal bodies. Its specific gravity is 1·336.

Heat produces the same effects on it as on potash. In the open air it absorbs water and carbonic acid, but it does not become liquid as potash does. After assuming the state of a paste it soon dries again and crumbles to powder.

It dissolves in water like potash, and may be obtained crystallized. The action of oxygen, of the simple combustibles and incombustibles, is similar to their action on potash. The same remark applies to the metals and their oxides.

Like potash, it is a compound of oxygen and a peculiar metal, to which Mr Davy, the discoverer, has given the name of *sodium*. It may be decomposed precisely in the same way as potash.

Sodium is a white metal like silver, solid, but very malleable, and so soft that pieces may be welded together by strong pressure. At 120° it begins to melt, and is completely fluid at 180°. It is not volatilized in a red heat strong enough to melt plate-glass. It conducts electricity and heat in the same manner as potassium. Its specific gravity is 0·9348.

Its affinity for oxygen is similar to that of potassium. When exposed to the air it is soon covered with a crust of soda, but as that alkali does not deliquesce, the nucleus is not so soon destroyed as happens to potassium. Hydrogen gas does not dissolve it. Hence no combustion takes place when sodium is thrown upon water, though it rapidly decomposes that liquid.

When fused with dry soda in certain quantities, there is a division of oxygen between the soda and the base, and a protoxide of sodium is formed of a deep brown colour.

It burns like potassium in oxymuriatic acid. It combines with phosphorus, sulphur and the metals like potassium. From the experiments of Mr Davy, it appears that soda is composed of

Sodium	78
Oxygen	22
	100

CHAP. III.

OF THE ALKALINE EARTHS.

The term *earth* in chemistry is applied to all substances possessing the following properties.

1. Insoluble in water, or at least becoming insoluble when combined with carbonic acid.
2. Little or no taste or smell; at least when combined with carbonic acid.
3. Fixed, incombustible, and incapable, when pure, of being altered by the fire.
4. A specific gravity not exceeding 4·9.
5. When pure, capable of assuming the form of a white powder.
6. Not altered when heated with combustibles.

The earths have been divided into two classes, namely, *alkaline earths* and *earths proper*. The alkaline are four in number; namely, *lime*, *magnesia*, *barytes* and *strontian*.

SECT. I. *Of Lime.*

Lime has been known from the remotest ages. It abounds in every part of the earth, constituting immense ranges of rocks and mountains. It may be obtained by *burning* those crystallized limestones called *calcareous spars*, or certain white marbles. Oyster shells, also, when burnt, yield it nearly pure.

Pure lime is white, moderately hard, but easily reduced to powder. Its taste is acrid like that of the fixed alkalies, and it in some measure corrodes those animal bodies to which it is applied. Its specific gravity is 2·3. It tinges vegetable blues green, and at last renders them yellow. It does not melt in the most violent heat that can be applied.

When water is poured upon it the lime swells and falls to pieces, and so much heat is evolved as to evaporate a portion of the water, and even to set fire to combustible substances with which it happens to be in contact. This process is called *slacking* the lime. A portion of the water combines with the lime and becomes solid. Hence the cause of the heat evolved. Slacked lime is composed of 3 parts lime and 1 water. It has been called *hydrate of lime*.

The difference between *limestone* and *lime* was first ascertained by Dr Black. Limestone is lime combined with carbonic acid. By burning it the carbonic acid is driven off and the pure lime remains.

When lime is exposed to the open air it gradually attracts moisture, falls to powder, and, becoming saturated with carbonic acid, soon resumes its original state of limestone.

Water dissolves less than 0·002 parts of its weight of lime. The solution is called lime-water. It is limpid, has an acrid taste, and changes vegetable blues to green. When exposed to the air, the lime soon combines with carbonic acid and precipitates, leaving the water pure.

Lime is not acted on by oxygen. Sulphur and phosphorus are the only two simple combustibles that unite with it.

Sulphuret of lime may be formed by mixing its two constituents together and heating them in a crucible. The mass has a reddish colour. In the air it becomes greenish yellow, sulphureted hydrogen is formed, and the mass is converted into *hydrogureted sulphuret of lime.* This last compound may be formed by boiling a mixture of sulphur and lime in about ten times its weight of water. The solution has a yellow colour, and is used for absorbing oxygen from air.

Phosphuret of lime may be formed by passing phosphorus through red-hot lime in a glass tube. It has a deep brown colour, and falls to powder in the air. When thrown into water, bubbles of phosphureted hydrogen gas are emitted, which take fire as they separate from the liquid.

Lime does not unite with azote, but it combines with muriatic acid, and forms a salt called muriate of lime.

Lime facilitates the oxidizement of several of the metals. It dissolves some metallic oxides, as those of mercury and lead.

It does not unite with the alkalies.

Mr Davy has lately ascertained that lime, like the fixed alkalies, is a compound of oxygen and a peculiar metal, to which he has given the name of *calcium.* He decomposed lime by exposing a mixture of moistened lime and red oxide of mercury to the action of a galvanic battery. A globule of mercury was placed in the middle of the mixture. The lime was decomposed, and its base united with the mercury and formed an amalgam. The mercury was distilled off in glass tubes filled with the vapour of naphtha, and the *calcium* remained behind.

Calcium is white like silver, solid, and four or five times heavier than water. When heated it burns brilliantly, and quick-lime is produced

SECT. II. *Of Magnesia.*

Magnesia was discovered about the beginning of the 18th century by a Roman canon. But little was known about its nature till Dr Black made his celebrated experiments on it in 1755.

It may be procured from the salt called *sulphate of magnesia*, or *epsom salt*, by dissolving the salt in water and pouring potash into the solution. A white matter falls; when washed and dried it is pure magnesia.

Magnesia is a very soft light powder, with very little taste and destitute of smell. Its specific gravity is 2·3. It tinges vegetable blues green. It does not melt in the strongest heat that can be raised.

It is not sensibly soluble in water, and has never been exhibited in a crystallized form. When exposed to the air it attracts carbonic acid very slowly.

It does not combine with oxygen nor with any of the simple combustibles except sulphur. The sulphuret of magnesia may be formed by mixing the two constituents and exposing it to a moderate heat. The result is a yellow powder slightly agglutinated.

It does not combine with azote, but unites with muriatic acid, and forms the salt called *muriate of magnesia*.

It has no action on the metals, nor is it known to combine with any of their oxides. Neither does it unite with the fixed alkalies or with lime.

Mr Davy succeeded in decomposing magnesia by the same process that furnished him with the base of lime. Like lime it is composed of oxygen and a metal, to which the name of *magnium* has been given. This metal is white, sinks rapidly in water, absorbs oxygen when exposed to the air, and is converted into magnesia. It decomposes water, but not nearly so rapidly as the other alkaline metals, owing doubtless to the insolubility of magnesia.

SECT. III. *Of Barytes.*

Barytes was discovered by Scheele in 1774. It is usually obtained from a heavy foliated brittle mineral, pretty common, and called *ponderous spar* or *sulphate of barytes*. This mineral is mixed with charcoal powder and exposed to a strong heat in a crucible. It is then dissolved in water and saturated with nitric acid. The liquid, filtered and evaporated, yields crystals, which being exposed to a strong heat in a crucible, leave behind them an earthy matter, which is barytes.

Barytes thus obtained is a greyish white porous body, and may be easily reduced to powder. Its taste is more caustic than that of lime, and when swallowed it acts as a violent poison. Its specific gravity is 2·374. When water is poured on it heat is evolved, and the barytes is *slacked* precisely as happens to lime. By this means it combines with water, and is converted into *hydrate of barytes*.

Water dissolves about 0·05 of its weight of barytes. The solution has an acrid taste and tinges vegetable blues green. Boiling water dissolves more than half its weight of barytes. As the solution cools, the barytes precipitates in crystals.

Barytes does not combine with oxygen, nor with any of the simple combustibles except sulphur and phosphorus. The sulphuret and phosphuret of barytes may be formed precisely in the same way as those of lime, which they resemble in most of their properties.

Barytes is not acted on by azote, but it combines with muriatic acid, and forms the salt called *muriate of barytes*.

Barytes has no action on the metals, but it combines with some of the metallic oxides, and forms compounds hitherto scarcely examined.

It does not combine with the alkalies, nor has it much action upon lime or magnesia.

Mr Davy has shown that barytes, like the preceding earths, is a metallic oxide, being composed of oxygen and a metal to which the name of *barium* has been given. The *barium* was obtained by the same process as that which furnished him the bases of lime and magnesia. It is a white solid metal, melts at a heat below redness, and is not volatilized at the temperature capable of melting plate glass. It is at least four or five times heavier than water. It decomposes that liquid with great rapidity, and is converted into barytes. It undergoes the same change when exposed to the open air.

SECT. IV. *Of Strontian.*

Strontian was first discovered in the lead mine at Strontian in Argyleshire. It was suspected to be a peculiar earth by Dr Crawford in 1790, and its properties were soon after investigated by Dr Hope. Klaproth and Kirwan also ascertained its peculiarity. It is found sometimes combined with carbonic acid, sometimes with sulphuric acid. From the first compound it may be obtained by making the mineral into a ball with charcoal powder and exposing it to a violent heat, and from the second by treating it precisely in the way described in the last section for obtaining barytes.

Strontian thus obtained is a porous mass of a greyish white colour. Its taste is acrid and alkaline, and it changes vegetable blues to green. Its specific gravity is 1·647. It is not poisonous.

When water is thrown upon it, the strontian becomes hot, combines with water, and is *slacked* like quick-lime. It is soluble in water, 162 parts of that liquid taking up one part of strontian. Hot water dissolves a much larger quantity, and the strontian crystallizes as the solution cools.

Strontian does not combine with oxygen. The only simple combustibles that unite with it are sulphur and phosphorus. The sulphuret and phosphuret of strontian may be formed precisely as the same compounds of lime, and possess nearly similar properties.

Strontian does not combine with azote, but it unites with muriatic acid, and forms the salt called muriate of strontian.

It has no action on the metals, but it combines with some of the metallic oxides. It does not unite with the alkalies, nor with the other alkaline earths.

It tinges flame of a beautiful red colour. The experiment may be made by setting fire to paper dipt in an alcoholic solution of muriate of strontian.

Mr Davy has ascertained that strontian, like the other alkaline earths, is composed of oxygen and a peculiar metal, to which he has given the name of *strontium*. This metal bears a close resemblance to *barium* in its properties.

CHAP. IV.

OF THE EARTHS PROPER.

The earths proper neither neutralize acids nor produce any change on vegetable blues. They are five in number; namely, *alumina*, *yttria*, *glucina*, *zirconia*, *silica*.

SECT. I. *Of Alumina.*

Alumina may be obtained from the salt called *alum* by the following process. Dissolve alum in water, pour ammonia into the solution. A precipitate appears, separate this precipitate and wash it. Then boil it in liquid potash till the whole is dissolved. Pour a solution of sal ammoniac into this liquid, a white matter precipitates, which, when washed and dried, is pure alumina.

Alumina is a white matter in powder. It has no taste, and when pure no smell. Its specific gravity is 2·000.

When heat is applied to alumina, it gradually loses weight in consequence of the evaporation of moisture. At the same time its bulk is diminished. Alumina undergoes a diminution of bulk proportional to the heat to which it is exposed. Mr Wedgewood took advantage of this property to contrive an instrument for measuring high temperatures. It consists of pieces of clay of a determinate size, and an apparatus for measuring their bulk with accuracy. One of these pieces is exposed to the heat, and the temperature is judged of by the contraction. This contraction is measured by means of two brass rules fixed to a plate. The distance between them at one extremity is 0·5 inch, and at the other extremity 0·3 inch. These rules are 24 inches long, and divided into 240 equal parts, called degrees. These degrees commence at the wide end of the scale. The first corresponds with 947° of Fahrenheit, or a red heat.

Alumina is not soluble in water, though it has a strong affinity for that liquid. It may be knedded with it into a very ductile paste possessed of a good deal of tenacity. Clay owes its ductility to the alumina which it contains. It retains water with more obstinacy than any of the other earths.

Alumina has no effect upon vegetable blues. It cannot be crystallized artificially, but it is found native in beautiful crystals, constituting the precious stone called sapphyr.

It neither combines with oxygen, nor with any of the simple combustibles.

Azote has no action on it; but muriatic acid unites with it, and forms the salt called *muriate of alumina*.

It does not unite with the metals, but it has an affinity for several metallic peroxides.

The fixed alkalies dissolve it readily when they are in a state of solution in water; but they do not melt with it when heated in a crucible. Barytes and strontian combine with alumina, both when heated with it in a crucible and when boiled with it in water. It has a strong affinity for lime, and easily melts with it when it exceeds the lime in quantity. But when the lime exceeds, fusion does not take place. Magnesia and alumina have no action on each other.

It is probable that alumina, like the alkaline salts, is a metallic oxide. This notion was entertained long ago by chemists. Davy endeavoured to obtain the metallic basis by means of galvanism, but did not succeed. Though he has rendered it probable that a metal exists in it. To this metal he proposes to give the name of *alumium*.

SECT. II. *Of Yttria.*

This earth was discovered by Gadoline in a Swedish mineral of a black colour, to which the name Gadolinite has been given. To obtain it, the mineral is reduced to powder, dissolved in nitro-muriatic acid, filtered, evaporated to dryness, re-dissolved, filtered, evaporated to dryness, the residual salt is heated to redness, re-dissolved in water, and ammonia poured into the solution. A white powder falls, which is yttria.

Yttria, thus procured, is a fine white powder without taste or smell. It has no action on vegetable blues. Heat does not melt it. Its specific gravity is 4·842.

It is insoluble in water, but, like alumina, it retains a portion of that liquid, though not with so much obstinacy.

It is insoluble in the liquid fixed alkalies; but it dissolves in carbonate of ammonia, and in all the other alkaline carbonates.

It does not combine with oxygen, the simple combustibles or azote, but with muriatic acid it forms the salt called *muriate of yttria.*

According to Ekeberg, when yttria is treated with muriatic acid, a quantity of oxymuriatic acid is formed. If so, it must contain oxygen, and of course be a metallic oxide. The opinion is probable, though no attempts have been made to decompose yttria by means of galvanism.

SECT. III. *Of Glucina.*

Glucina was discovered by Vauquelin in the two minerals called beryl and emerald. They are pounded and fused with thrice their weight of potash. The mass is dissolved in muriatic acid and the solution evaporated to dryness. The residuum is digested in water and thrown upon the filter. The liquid which passes through is mixed with carbonate of potash, and the precipitate dissolved in sulphuric acid. Sulphate of potash being added to the solution, it is laid aside for some time. Alum crystals gradually form. When no more appear, filter the liquid, add carbonate of ammonia in excess, filter again and boil the liquid for some time. A white powder precipitates, which is glucina.

Glucina is a soft white powder, without either taste or smell. It adheres strongly to the tongue, produces no change on vegetable blues, does not melt when heated, and does not harden and contract like alumina. Its specific gravity is 2·976. It is insoluble in water, but forms with it a paste having some ductility.

It does not combine with oxygen, nor with the simple combustibles or azote; but with muriatic acid it forms the salt called *muriate of glucina.*

It is soluble in the liquid fixed alkalies, like alumina; is insoluble in ammonia, but, like yttria, soluble in carbonate of ammonia.

Mr Davy has rendered it probable that it is a metallic peroxide. To the metallic basis he proposes to give the name of *glucium*.

SECT. IV. *Of Zirconia.*

Zirconia was discovered by Klaproth in the two minerals called *jargon* or *zircon*, and hyacinth. Fuse the pounded mineral with thrice its weight of potash. Wash the mass in pure water till the whole of the potash is extracted; then dissolve the residuum as far as possible in muriatic acid. Boil the solution, filter and add a quantity of potash. The zirconia precipitates in the state of a fine powder.

Zirconia is a white powder with a harsh feel. It has neither taste nor odour, infusible before the blowpipe, but when violently heated, acquires the appearance of porcelain. In this state it is hard, and its specific gravity is 4·3. It is insoluble in water, but, when precipitated from a solution and dried slowly, it retains water and assumes the appearance of gum arabic.

It does not combine with oxygen, simple combustibles, azote, nor metals. But it has an affinity for several metallic oxides.

It is insoluble in liquid alkalies and infusible with them; but it is soluble in alkaline carbonates.

Mr Davy has made it probable that it is a metallic peroxide. To the metallic basis he proposes to give the name of *zirconium*.

SECT. V. *Of Silica.*

The minerals called *quartz, rock-crystal, flint,* &c. consist almost entirely of this earth. It may be obtained in the following manner. Melt in a crucible a mixture of one part quartz powder and three parts potash. Dissolve the mass in muriatic acid, and evaporate to dryness. Towards the end of the evaporation, the liquid assumes the form of a jelly. Wash the residue in water and dry it.

Silica thus obtained is a fine white powder with a harsh feel, and without either taste or smell. Its specific gravity is 2·66. It has no effect on vegetable colours, is insoluble in water, and infusible by the heat of our furnaces. It does not form a ductile paste with water like alumina. It is found native crystallized, most commonly in hexagonal prisms, terminated by six-sided pyramids.

It does not combine with oxygen, the simple combustibles, simple incombustibles, or the metals. It may be fused with several of the metallic oxides.

The fixed alkalies may be fused with it into glass. Ammonia has no action on it. It may be combined with barytes, strontian, lime and magnesia by heat. There is a strong affinity between it and alumina.

Mr Davy has rendered it probable that silica, like the other earths, is a metallic peroxide. To the metallic basis of it he proposes to give the name of *silicium.*

DIVISION II.

OF PRIMARY COMPOUNDS.

The only primary compounds that can be at present placed under this division, may be arranged under the following heads. 1. Oxides; 2. Acids; 3. Compound combustibles.

CHAP. I.

OF OXIDES.

Many bodies, as we have seen already, are capable of combining with oxygen. Now the compounds into which oxygen enters are of two kinds. They either possess the properties of *acids,* or they are destitute of these properties. To the first class the term *acid* has been applied; to the second that of *oxide.* By *oxide,* then, is meant a combination of oxygen and some other substance destitute of the properties belonging to acids. It is very common to find the same base combine with different doses of oxygen, and form both *acids* and *oxides.* In all these cases, the *smaller* proportion of oxygen constitutes the *oxide,* and the *larger* the *acid.* Hence it follows, that oxides always contain less oxygen than acids with the same base.

The oxides which we have to examine are combinations of oxygen with the simple combustibles and incombustibles. For the metallic oxides have been already described in the first book, while treating of the metals. All that is known of the oxides of phosphorus and sulphur has also been stated. To all the combinations of muriatic acid and oxygen, the name of *acids* has been given. We have only to examine in this place, therefore, the oxides of hydrogen, carbon and azote.

SECT. I. *Of the Oxide of Hydrogen or Water.*

This well known liquid is found in abundance in every part of the world. When pure, in which state it may be obtained by distillation, it is destitute of colour, taste and smell.

At the temperature of 40°, a cubic foot of pure water weighs 437102·4946 grains troy, or 999·0914161 ounces avoirdupois. Hence a cubic inch of water at 40°, weighs 252·953 grains; and at 60°, 252·72 grains. The specific gravity of water is always supposed 1·000, and it is made the measure of the specific gravity of every other body.

When cooled down to 32°, it crystallizes and becomes *ice*. At 212°, it boils and is converted into *steam*, an elastic fluid, invisible like air, and about 1800 times more bulky than water. The boiling point of water is somewhat altered by dissolving salt in it. Some salts raise the boiling point, others lower it a little, while some produce both effects according to the proportion employed.

Water is not altered by heat. It absorbs a little air and a certain proportion of all gases exposed to it. By long boiling, or by being placed in an exhausted receiver, it is freed from the greatest part of this air.

Water has no action on the simple combustibles while cold. But, at a red heat, charcoal decomposes it. The action of phosphorus is not known. Sulphur, as far as is known, does not decompose it.

Of the metals iron, zinc, antimony and tin decompose it when assisted by heat; silver, gold, copper and platinum have no effect on it. The action of the other metals has not been ascertained. The metallic bases of the alkalies and earths decompose it with great rapidity at the usual temperature of the atmosphere.

Water dissolves the alkalies and alkaline earths. The earths proper are insoluble in it. It dissolves also acids and salts; and is capable of combining with a great variety of bodies. Water unites to bodies two different ways. Some it dissolves and the compound becomes liquid like water. In this way it dissolves sugar, common salt, and many other bodies. Other bodies combine with it without losing their solidity. The water loses its liquid form and assumes that of the body with which it unites. In this way it combines with lime, with alumina, with many salts, and with various metallic oxides. When the compound of water with another substance remains liquid, the proportion of water is unlimited; but when the compound formed is solid, the water combines always in a certain determinate proportion. To the first kind of compound, the name of *solution* has been given; to the second, the term *hydrate* has been applied. Thus, *slacked lime* is called *hydrate of lime*; the crystals of barytes and strontian are called *hydrates of barytes and strontian.* Most of the metallic hydrates have lively colours, a strong taste and are easily soluble in acids, while the oxide which constitutes the base of the hydrate is usually duller in its colour, often tasteless and always more difficultly soluble in acids. The hydrate of copper is blue, that of nickel and iron green, that of cobalt red, and that of tin white.

All the gases, in their usual state, contain a quantity of water, from which they are best freed by exposure to a very low temperature. But this method does not succeed in freeing muriatic acid gas from water. That gas, even at the lowest temperatures, contains about one-fourth its weight of water.

The ancients considered water as an elementary substance. Van Helmont endeavoured to prove that plants could be nourished by pure water alone, and of course that it could be converted into all the substances found in vegetables. Boyle thought that, by long digestion in glass vessels, it could be converted into silica. His experiment was confirmed by Margraff. But Scheele and Lavoisier proved that the silica was obtained by the decomposition of the glass vessel in which the experiment was made. Mr Cavendish, in 1781, ascertained that water is a compound of oxygen and hydrogen, nearly in the proportion of six parts of the former and one of the latter; and this discovery was confirmed by a number of very laborious and rigid experiments.

SECT. II. *Of Carbonic Oxide.*

The substance at present known by the name of *carbonic oxide*, is a gas which was confounded with carbureted hydrogen, till Dr Priestley drew the attention of chemists to it in a dissertation which he published in defence of the doctrine of phlogiston. It was examined, in consequence, by Mr Cruikshanks, who showed it to be a compound of *oxygen* and *carbon*, and not of *hydrogen* and *carbon*, as Priestley had supposed. Clement and Desormes also analysed it with the same result.

It may be obtained most readily by mixing together equal weights of iron-filings and chalk, each as dry as possible, and exposing them to a red heat in an iron retort. A gas comes over in abundance. It consists partly of *carbonic acid*, partly of *carbonic oxide*. The first gas is removed by washing in lime-water. The carbonic oxide remains behind.

Carbonic oxide is invisible; and possesses the mechanical properties of common air. Its specific gravity is 0·956, that of air being 1·000. No animal can breathe it without death. No combustible substance will burn in it.

It burns with a blue flame, giving out but little light, and is wholly converted into carbonic acid gas. When mixed with oxygen gas and kindled by means of an electric spark, 100 parts of it require 45 parts by bulk of oxygen gas for complete combustion. The result is about 90 parts of carbonic acid gas. From this experiment it has been deduced that carbonic oxide is composed of

41 carbon.
59 oxygen.

100

The simple combustibles have but little action on this gas. Hydrogen has none even at a red heat; nor charcoal nor sulphur. But it dissolves a little phosphorus, and acquires the property of burning with a yellow flame.

The simple incombustibles have no effect on it at any temperature tried. But oxymuriatic acid gas gradually destroys it, converting it into carbonic acid gas. This mixture cannot be kindled by electricity; whereas a mixture of oxymuriatic acid and carbureted hydrogen, burn directly when an electric spark is passed through them.

Its action on metals and their oxides has been but imperfectly examined. Neither the alkalies nor the earths have any action on it whatever.

SECT. III. *Of the Oxides of Azote.*

Azote and oxygen form two different oxides, both gases, and both discovered by Dr Priestley. The first has been called *nitrous oxide gas*, the second *nitrous gas*, or *nitric oxide gas*.

1. *Nitrous Oxide Gas.*

This gas was discovered by Dr Priestley in 1776 and called by him *dephlogisticated nitrous gas.* The associated Dutch chemists examined it in 1793, and ascertained its composition. But for the best account of it we are indebted to Mr Davy.

It may be obtained by exposing the salt called *nitrate of ammonia* in a retort to a heat between 340° and 500°. It melts and emits abundance of gas, which may be collected in jars of water.

Thus obtained, it has all the mechanical properties of air. Its specific gravity is 1·603, that of air being 1·000.

It supports combustion better than common air, almost as well as oxygen gas, but for a much shorter time. But combustibles do not burn in it, unless previously in a state of ignition.

It may be breathed for a short time, and produces effects similar to intoxication.

Water absorbs nearly its own bulk of this gas, and acquires a sweetish taste; but its other properties are not perceptibly altered. It may be driven off from the water unaltered by means of heat.

It is not altered by light, nor by a moderate heat. But by a red heat it is decomposed and converted into *nitric acid* and *common air.*

Oxygen, or common air, has no action on this gas.

Sulphur, if introduced into this gas while burning with a blue flame, is immediately extinguished; but, if it be burning with a violet flame, it continues to burn for some time with great brilliancy with a fine red flame. The products are sulphuric acid and azote.

Phosphorus, when touched with a wire white hot, burns with great brilliancy in this gas. The products are azotic gas, phosphoric acid and nitric acid.

Charcoal may be kindled in it by means of a burning glass. The products are carbonic acid gas, and azotic gas.

Hydrogen detonates with it by means of electricity. According to Mr Davy, 39 measures of nitrous oxide consume 40 measures of hydrogen, and after the combustion 41 measures of azotic gas remain. From this experiment it has been concluded, that nitrous oxide is composed by weight of

63 azote.
37 oxygen.

100

Sulphureted, phosphureted and carbureted hydrogen gas likewise burn when mixed with nitrous oxide, and kindled.

Neither azote nor muriatic acid produce any effect upon this gas.

Some of the metals as iron and zinc, burn or may be oxydized in it.

It has the property of combining with alkalies, and of forming a peculiar species of salt, to which the name of *azotites* may be given. Mr Davy, to whom we are indebted for the discovery of these compounds, did not suceeed in combining nitrous oxide with ammonia and the earths, but he has rendered it probable that such compounds are possible.

2. *Nitrous Gas.*

This gas was accidentally obtained by Dr Hales, but its properties were first investigated, and its nature ascertained by Dr Priestley.

To obtain it, dissolve copper or silver in nitric acid diluted with water, a gas separates, which may be collected in jars over water, and is the gas in question.

It possesses the mechanical properties of common air. Its specific gravity is 1·094, that of air being 1·000.

It is exceedingly noxious to animals, producing instant suffocation whenever they attempt to breathe it.

Most combustible substances refuse to burn in it. But pyrophorus burns in it with great splendour, and Homberg's phosphorus takes fire in it spontaneously just as in common air. Dr Henry has ascertained, that ammoniacal gas, when mixed with it, detonates by means of electricity.

When mixed with common air or oxygen gas, a yellow colour appears, and if the mixture be standing over water, its bulk gradually diminishes very considerably. The yellow colour is owing to the presence of nitrous acid which is formed, and the diminution of bulk to the gradual absorption of that acid by the water. The cause of this remarkable phenomenon is obvious. The nitrous gas combines with the oxygen, and forms nitrous acid. Hence the diminution of bulk depends upon the quantity of oxygen present. There is a good deal of difference in the result obtained by chemists of the amount of the diminution of bulk, which ensues. According to Dalton, 21 measures of oxygen gas unite either with 36 measures of nitrous gas, or with 72 measures. According to Gay-Lussac 100 measures of oxygen gas unite either with 200 or with 300 measures of nitrous gas, according to circumstances.

Nitrous gas, by electricity, is converted into nitrous acid and azote.

Water, according to Dr Priestley, absorbs about 1-10th its bulk of this gas; according to Dr Henry about 1-20th of its bulk.

It is decomposed by phosphorus and charcoal, and probably also by sulphur at a very high temperature. Hydrogen gas mixed with it burns with a green flame. This mixture, according to Fourcroy, detonates when passed through a red hot tube.

Neither azote nor muriatic acid produce any effect upon it.

Several of the metals decompose it. When kept for some time in contact with iron, its bulk diminishes, and it is coned into nitrous oxide.

It is absorbed unchanged by a solution of green sulphate or muriate of iron. The liquid acquires a deep brown colour; and, when kept, becomes blue. The gas may be expelled unaltered by heat.

The following bodies convert this gas into nitrous oxide. Alkaline sulphites, hydrogureted sulphurets, muriate of tin, sulphureted hydrogen-gas, iron or zinc filings moistened with water.

From the analysis of Mr Davy, it appears to be composed by weight of

57	oxygen.
43	azote.
100	

According to Gay-Lussac nitrous gas is composed of equal bulks of oxygen and azotic gas united together, and its specific gravity is exactly the mean. Hence no change of bulk takes place when they are combined. This would give us nitrous gas composed by weight of

53	oxygen.
47	azote.
100	

CHAP. II.

OF ACIDS.

The word *acid*, originally synonymous with *sour*, is at present applied to all bodies possessed of the following properties.

1. When applied to the tongue, they excite that sensation which is called *sour* or *acid*.

2. They change the blue colours of vegetables to red.

3. They unite with water in almost every proportion.

4. They combine with the alkalies, earths, and metallic oxides, and form a class of bodies called *salts*.

Every acid does not possess the whole of these properties. But all of them possess a sufficient number to distinguish them from other bodies. The 2d and 4th properties are considered as the most important and essential.

It was at one time believed that there existed only one acid in nature, and that all bodies owed their acidity to the presence of that acid.

This notion was long a favourite one among chemists, and sulphuric and phosphoric acids were pitched upon as the universal acids. But the claims of neither could stand the test of a rigid examination. At last Mr Lavoisier proved that many substances were capable of combining with *oxygen*, and by that means were converted into acids. Hence oxygen was termed the *acidifying principle*.

All that can be meant by this appellation is only that many acids contain oxygen as a constituent, and that when deprived of oxygen, they lose their acid characters. In this sense the appellation is correct enough. But it is not true that oxygen itself possesses acid characters; neither has it been proved that it exists in every acid. Many substances contain oxygen which are entirely destitute of acid properties. Thus water, alkalies, and alkaline earths contain it. Yet it would be absurd to consider any of these bodies as acids. As the acids are very numerous, and very heterogeneous in their properties, it will be of some importance to subdivide them into classes. They may be arranged under three heads: 1. Acid products. 2. Acid supporters. 3. Combustible acids.

CLASS 1. *Acid products.*

All the acids belonging to this class possess the following properties.

1. They may be formed by combustion, Of course their base is a simple combustible.

2. They are incombustible.

3. They resist a violent heat without decomposition. But to this there are some exceptions.

4. They are decomposed by the joint action of a combustible body and caloric.

5. Oxygen is an essential ingredient in all of them.

Some of the combustibles combine with two doses of oxygen, and form two distinct acids. When that happens, the acid containing the smallest dose of oxygen is distinguished by the termination *ous*, while that which contains a maximum of oxygen is distinguished by the termination *ic*. Thus *sulphurous* and *sulphuric acids*. The first contains the least, and the second the most oxygen.

The following table exhibits the names of the acid products, their bases, and the proportion of oxygen in each, combined with 100 of the bases as far as it is known at present.

Names.	*Bases.*	*Proportion of oxygen to 100 base.*
Sulphuric	Sulphur.	136·5
Sulphurous		88·6
Phosphoric	Phosphorus	114·7
Phosphorous		58 ?
Carbonic	Carbon	257
Boracic	Boracium	200
Fluoric	Unknown	

SECT. I. *Of Sulphuric Acid.*

Sulphuric acid seems to have been discovered by the alchymists. It was long obtained by distilling the salt called *green vitriol,* or *sulphate of iron.* Hence the names *oil of vitriol* and *vitriolic acid* originally applied to it. It is now procured by burning a mixture of sulphur and nitre in chambers lined with lead, the bottom of which is covered with water. The acid formed is dissolved by the water, and is concentrated by distillation in glass retorts.

Sulphuric acid is liquid, somewhat of an oily consistency, transparent and colourless as water, without any smell, and of a very strong acid taste. It destroys the texture of animal and vegetable substances. Its specific gravity, when as strong as possible, is about 1·85. It changes all vegetable blues to red, except indigo. It boils at 546°. When exposed to cold, it crystallizes or congeals. The temperature necessary depends upon the strength. When of the specific gravity 1·780, it freezes at 45°. When stronger or weaker, it requires a much greater degree of cold.

It has a strong attraction for water, and when exposed to the atmosphere, imbibes nearly 7 times it weight of that liquid. When the two liquids are mixed together, a considerable heat is evolved. Thus 4 parts of acid and 1 of water raises the thermometer to about 300°. The density of this mixture is always considerably greater than the mean. From the experiments of Kirwan, it appears that the strongest sulphuric acid of commerce contains almost 1-5th of water, the remaining 4-5ths are pure acid.

From the most accurate experiments hitherto made, sulphuric acid appears to be composed of

42·3	oxygen.
57·7	sulphur.
100·0	

This acid is not altered by exposure to light nor heat. Oxygen gas does not act upon it nor combine with it.

The simple combustibles have but little effect upon it at the ordinary temperature of the atmosphere, but when assisted by heat they all decompose it. When hydrogen gas and the acid are passed through a red hot tube, water is formed and sulphur deposited. Charcoal absorbs oxygen from it and readily converts it into sulphurous acid, or into sulphur, if the heat be long continued. Phosphorus and boracium produce the same effect. Sulphur, when boiled with it, readily converts it into sulphurous acid.

Azote has no action on it; but it readily absorbs muriatic acid, and forms a smoking compound, which acts powerfully upon some metals.

Sulphuric acid, when concentrated, has little action on the metals. When diluted, it dissolves iron and zinc with rapidity, water is decomposed, and hydrogen gas emitted. When heated, it oxidizes several of the metals, and sulphurous acid is exhaled. On gold and platinum it produces no effect whatever.

It unites readily with the alkalies, earths and metallic oxides, and forms with them a class of bodies called *sulphates*.

It absorbs a good deal of nitrous gas, and acquires, in consequence, a purplish colour.

This acid is of great importance both in chemistry and the arts.

SECT. II. *Of Sulphurous Acid.*

The existence of this acid was pointed out by Stahl, but Priestley was the first who procured it in a separate state. It may be obtained by distilling, in a retort, a mixture of two parts sulphuric acid and one part of mercury. An effervescence takes place, and a gas comes over which may be received in jars over mercury.

It is colourless, and possesses the mechanical properties of common air. It has a strong and suffocating odour, precisely the same as that emitted by burning sulphur. Its specific gravity is 2·265, that of air being 1·000. It reddens vegetable blues, and gradually destroys the colour altogether.

When strongly heated, sulphur is deposited and sulphuric acid formed. When exposed to the temperature of —18°, it is condensed into a liquid.

Water absorbs 33 times its bulk of this gas. The liquid has the smell of the gas, an acid and sulphureous taste, and the specific gravity 1·0513. It may be frozen without parting with the gas. But when heated the gas is expelled. When this liquid is left to itself, it gradually absorbs oxygen and the acid is converted into the sulphuric.

Sulphur and phosphorus seem to have no action on this acid, but hydrogen and charcoal decompose it when assisted by heat, and sulphur is evolved. Neither azote nor muriatic acid produce any effect upon it.

It oxidizes and dissolves iron, zinc and manganese.

It combines with the salifiable bases, and forms salts called *sulphites*.

Sulphuric acid absorbs it, and forms a singular compound called *glasial sulphuric acid*, which readily becomes solid, and smokes when exposed to the air.

Its constituents, according to my experiments, are

53	sulphur.
47	oxygen.
100	

SECT. III. *Of Phosphoric Acid.*

This acid was first mentioned by Boyle, but its properties were investigated many years after. It may be obtained by burning phosphorus, or by dissolving phosphorus in nitric acid, and evaporating the liquid to dryness.

In this state it is solid, colourless and transparent, not unlike glass. It reddens vegetable blues, has no smell, but has a very acid taste. When exposed to the air, it attracts moisture and gradually runs into an oily-like fluid. Its specific gravity, when in the state of glass, is 2·8516; when in the liquid state 1·417.

It is very soluble in water, and is said to be capable of crystallizing, but it is difficult to obtain it in that state.

Oxygen has no effect upon it. None of the simple combustibles are known to be capable of decomposing it, except charcoal. When strongly heated with this substance, phosphorus is disengaged. The simple incombustibles have no effect on it.

It is capable of oxidizing and dissolving some of the metals. But its action on these bodies is by no means strong.

It combines with the salifiable bases, and forms a class of salts called *phosphates.*

According to the experiments of Rose, it is composed of

46·5	phosphorus.
53·5	oxygen.
100·0	

SECT. IV. *Of Phosphorous Acid.*

This acid was known earlier than the preceding. For a long time they were confounded. Lavoisier was, perhaps, the first who accurately distinguished them. It may be obtained by exposing phosphorus to the open air: it gradually absorbs oxygen and runs into a liquid, which is the acid in question.

It is a viscid colourless liquid; having a very acid taste, and emitting the smell of garlic, especially when heated. It combines with water in any proportion. When evaporated to dryness and heated, it gives out phosphureted hydrogen gas, which burns when it comes in contact with the air. This continues for a long time, and at last the acid is converted into the phosphoric. If nitric acid be poured upon it, this change takes place much more easily and speedily.

The action of the simple combustibles, the incombustibles and the metals on this acid, is similar to their action on phosphoric acid.

It combines with the different salifiable bases, and forms a class of salts called *phosphites.*

Sulphuric acid, by the assistance of heat, converts it into phosphoric acid.

It has been ascertained that this acid contains less oxygen than the phosphoric, but the actual proportion has not been determined,

SECT. V. *Of Carbonic Acid.*

This acid was discovered by Dr Black. Its properties were afterwards investigated by Mr Cavendish and Dr Priestley, and its composition ascertained by Mr Lavoisier. It was at first called *fixed air.* Mr Lavoisier, after ascertaining its base, gave it the name which it now bears. Every chemist almost of eminence, during the last 50 years, has added something to our knowledge of the properties of this remarkable substance.

It may be obtained by burning charcoal, or more easily by pouring muriatic acid on chalk in a glass retort, and receiving the gas which is extricated in glass jars over water. This gas is the acid in question.

It is invisible, and possesses the mechanical properties of air. No combustible will burn in it. It is unfit for respiration. It affects the nostrils with a kind of pungent sensation, but when diluted with air, it has no smell whatever. Its specific gravity is 1·500, that of air being 1·000. It reddens very delicate vegetable blues.

Atmospheric air contains about $\frac{1}{1000}$ of its bulk of this gas.

It is not altered by passing it through a red hot tube, but but when electric sparks are passed through it for a long time its bulk increases, and a portion of carbonic oxide is evolved.

Water absorbs it when placed in contact with it. The rapidity of the absorption is much increased by agitation. Water absorbs its own bulk of this gas at the temperature of 41°. The water acquires a sour taste, a sparkling appearance, and the property of reddening vegetable blues. When heated or frozen, the gas is extricated. It makes its escape also if the liquid be left exposed to the open air.

Carbonic acid is not acted upon by oxygen; nor, as far as is known, is it altered by any of the simple combustibles, incombustibles or metals. But several of these bodies, as charcoal, phosphorus and different metals, have the property of decomposing it at a red heat, when it is in combination with lime, barytes or strontian. In these cases a quantity of carbonic oxide is usually evolved.

It combines with the salifiable bases, and forms a class of salts called *carbonates*.

From the most exact experiments hitherto made, we may consider this acid as composed very nearly of

28 carbon.
72 oxygen.

100

SECT. VI. *Of Boracic Acid.*

This acid is obtained from the salt called *borax*, brought to Europe from the east, where it is found chiefly at the bottom of some lakes in Thibet and China. It was first extracted from borax by Homberg, and its nature was ascertained by Baron. To obtain it, dissolve borax in hot water and add sulphuric acid till the liquid assumes a sensibly acid taste. As the liquid cools, it deposites white crystalline scales, which are *boracic acid.*

Thus obtained, it has the form of thin hexagonal scales of a silvery whiteness. Its taste is sourish and bitterish. It has no smell. It reddens vegetable blues. Its specific gravity, while in scales, is 1·479, when melted 1·803.

It is not altered by light nor heat. In a red heat it melts into a transparent colourless glass, which becomes somewhat opake when exposed to the air, but does not attract moisture.

Boiling water does not dissolve more than 0·02 of this acid, and cold water still less.

Neither oxygen, the simple combustibles, incombustibles or metals, produce any effect upon this acid. But when heated with potassium it is decomposed, and its base *boracium* separated.

From the experiments of Davy, we may conclude that boracic acid is composed of about 33 boracium.
67 oxygen.

100

It is soluble in alcohol, and alcohol containing it burns with a green coloured flame. It dissolves also in some of the oils.

It is hardly capable of oxidizing any of the metals except iron and zinc.

It combines with the salifiable bases, and forms a class of salts called *borates*.

SECT. VII. *Of Fluoric Acid.*

This acid was discovered by Scheele. He obtained it from a pretty common and beautiful mineral called *fluor spar*, and in this country often Derbyshire spar. This mineral is a compound of fluoric acid and lime. Dr Priestley first obtained the acid in a separate state.

To procure this acid, pour sulphuric acid on the pounded spar and apply heat. A gas comes over which must be received over mercury. It is the acid in question.

This gas possesses the mechanical properties of air. It does not support combustion, nor can animals breathe it. It smokes when mixed with the atmosphere, and has a smell similar to that of muriatic acid.

It is not altered by exposure to heat or light.

Water absorbs it rapidly. If glass vessels have been employed to procure it, a jelly is deposited as soon as it comes in contact with the water. This jelly consists of silica which the gas has dissolved from the glass, and which it held in solution. No method has been yet discovered of obtaining fluoric acid gas free from foreign matter. If leaden vessels be used, the gas does not assume the elastic form, at least I could not procure it by means of these vessels. When fluor spar and vitreous boracic acid are heated together, a gas is obtained, which is a combination of the two acids, to which sphere. Its taste is extremely acid, and it is one of the most corrosive substances known, tinging the skin instantly of an indelible yellow, and very soon destroying its texture entirely. It converts vegetable blues to red. Its specific gravity, when strongest, never exceeds 1·583. It contains, mixed with it, a considerable portion of water, from which it cannot be freed. When strongest, this water amounts to about one-fourth of the whole.

It boils at 248°, and may be distilled over without alteration. When cooled sufficiently it congeals, and the freezing point varies exceedingly according to the strength of the acid. There is a certain strength at which it congeals most easily, and, if it be either stronger or weaker, the freezing point is considerably lower.

Oxygen has no effect upon this acid; but all the simple combustibles decompose it. When poured upon charcoal, phosphorus or sulphur, at a high temperature, it sets them on fire. When diluted, it effervesces with these bodies, and acidifies them. Hydrogen gas does not act upon it at the common temperature of the atmosphere, but when passed with it through a red-hot tube, it detonates, water is formed and azotic gas disengaged. Boracium is readily converted by it into boracic acid. When poured upon the volatile oils, and even upon several of the fixed oils, it sets them on fire. If it be previously mixed with a little sulphuric acid, it sets almost all the oils on fire.

Azote has no action on this acid, but muriatic acid forms with it the compound called *aqua regia*, or *nitro-muriatic acid*.

It is capable of oxidizing all the metals except gold, platinum and titanium. With most of the oxides it combines, though some, as the peroxides of tin and antimony, are insoluble in it. It even sets fire to some of the metals when poured upon them in fusion.

water, and muriatic acid remains behind. This mixture explodes by electricity.

Charcoal is said by some to burn in it when introduced about the temperature of 90°. Phosphorus takes fire in it, and is converted into phosphoric acid. Sulphur is gradually acted on by it, and a red liquid formed, composed of muriatic acid, oxygen and sulphur, to which the name of sulphureted muriatic acid has been given. Boracium is speedily converted into boracic acid. Sulphureted, carbureted and phosphureted hydrogen gases likewise decompose this acid, but only the last of them burns spontaneously when mixed with it.

Neither of the simple combustibles produces any effect upon this gas.

It oxidizes all the metals with facility, and even sets fire to several of them, and burns them.

Ammoniacal gas likewise takes fire spontaneously, and burns with considerable splendour when mixed with this gas, the result is water and sal ammoniac.

It seems capable of uniting with the different bases, when they are presented to it in a dry state, but water in general seems sufficient to prevent the combination from taking place. The salts formed are called *oxymuriates*.

It reddens nitrous gas, converting it into nitric acid. Sulphurous and phosphorous acids are converted by it into sulphuric and phosphoric acids. Upon the other acids already described, it produces no effect.

When nitric and muriatic acids are mixed together, a quantity of oxymuriatic acid gas is separated.

From the analysis of Chenevix, it appears that this acid is composed of

77·5 muriatic acid.
22·5 oxgen.

100·0

SECT. IV. *Of Hyperoxymuriatic Acid.*

This acid was discovered by Berthollet. Its nature and peculiarities were farther investigated by Chenevix.

If a solution of potash in six times its weight of water be put into a Woulfe's bottle, and a current of oxymuriatic acid gas be passed through it for a sufficient time, small brilliant crystals are deposited in scales. These crystals have received the name of *hyperoxymuriate of potash.* They possess curious and important properties. The liquid contains another salt composed of *muriatic acid* and *potash.* From this last fact it was inferred, that the acid in the first salt contained more oxygen than exists in oxymuriatic acid. This was demonstrated by the experiments of Chenevix, who showed that it was composed of

66	oxygen.
34	muriatic acid.
100	

All attempts to procure this acid in a separate state have failed. When sulphuric or nitric acid is poured upon the salt, it is dissolved, assumes an orange colour, and a greenish yellow vapour floats above the solution. When heat is applied to drive off the acid, a violent detonation takes place, which shatters the vessel to pieces. When muriatic acid is poured upon the crystals, an effervescence takes place, and a gas is separated intermediate in its properties between oxymuriatic acid and hyper-oxymuriatic acid.

When this salt is rubbed with sulphur, phosphorus or charcoal, or when struck with these bodies on an anvil, a violent detonation take place, and the combustible substances are burnt. The same phenomena take place when the salt is struck after being mixed with a variety of other combustible substances. Gunpowder may be made of it more powerful than common gunpowder, but the manufacture is attended with risk, in consequence of the tendency which the ingredients have to detonate when rubbed.

SECT. V. *Of Arsenic Acid.*

This acid was discovered by Scheele. It may be formed in the following manner: Mix in a retort one part of muriatic acid, four parts of white oxide of arsenic, and 12 parts of nitric acid of the specific gravity 1·25. Boil the mixture till the oxide disappear, and nitrous fumes cease to be disengaged; then evaporate to dryness, and expose the mass to a low red heat. The matter thus obtained is solid *arsenic acid.*

It is a white solid mass nearly tasteless, of the specific gravity 3·391. It is very fixed. It melts at a red heat, and is converted into glass.

It dissolves slowly in cold, but rapidly in hot water, and by cautious evaporation may be obtained in crystals. The taste of the solution is acid, caustic and metallic.

Oxygen has no effect on it. The simple combustibles decompose it when assisted by heat, and sometimes take fire, in consequence of its action on them, a proof that this acid is a supporter of combustion.

The simple incombustibles have no action on it. It oxidizes several of the metals, especially when assisted by heat.

It combines with the salifiable bases, and forms a class of salts called *arseniates.*

It has no action on any of the acids already described.

From the analysis of Proust, it appears that this acid is composed of

65 arsenic.
35 oxygen.

100

SECT. VI. *Tungstic Acid.*

The substance originally called tungstic acid was discovered by Scheele. It was not pure, being contaminated by the acid employed in separating it.

The real tungstic acid is a yellow powder first described by the Eluyarts. It is tasteless, insoluble in water, and has no effect on vegetable blues. It is rather an oxide than an acid. But it combines with the salifiable bases, and forms a class of salts called *tungstates*.

SECT. VII. *Of Molybdic Acid.*

This acid was discovered by Scheele. It has been lately examined by Bucholz.

It may be obtained by digesting nitric acid on molybdena till the whole is converted into a white mass. Edulcorate this mass with water, the residue is molybdic acid.

It is a white powder of the specific gravity 3·460. In close vessels it melts and crystallizes when heated; but in open vessels it sublimes, and may be collected in the form of brilliant yellow scales.

It is soluble in 960 parts of water. The solution is pale yellow. It is tasteless, but reddens vegetable blues.

Molybdic acid is not affected by oxygen gas; but it is decomposed by sulphur and charcoal, and several of the metals.

It combines with the salifiable bases, and forms a class of salts called *molybdates*.

It dissolves in sulphuric acid. The solution is colourless when hot, but becomes blue when cold. It dissolves also in muriatic acid, but not in nitric acid.

According to the analysis of Bucholz, it is composed of

67 molybdenum.
33 oxygen.

100

Sect. VIII. *Of Chromic Acid.*

This acid was discovered by Vanquelin. It may be obtained from the *red lead ore* of Siberia, by boiling the ore with carbonate of soda, decanting off the fluid solution, and saturating it with sulphuric acid. A red powder falls, which is *chromic acid.*

It has a red or orange yellow colour, an acrid and metallic taste; is soluble in water, and crystallizes in elongated prisms of a ruby colour.

When heated it gives out oxygen gas, and is converted into green oxide of chromium.

When mixed with filings of tin and muriatic acid, it becomes at first yellowish brown, and afterwards assumes a beautiful green colour. When treated with acids, and various other combustibles, a green colour is also evolved.

Sect. IX. *Of Columbic Acid.*

This acid was discovered by Hatchet in an ore from America of a black colour, which he found in the British Museum. It was obtained by fusing the ore with potash, dissolving the potash in water, and adding nitric acid to the solution. The columbic acid precipitated in flakes.

It is a powder of a white colour, and not very heavy. It is tasteless, insoluble in water, but gives a red colour to vegetable blues.

Sulphuric acid dissolves it, and forms a colourless solution, from which the columbic acid is precipitated by water. It is soluble also in muriatic acid, but not in nitric acid.

It combines with the salifiable bases, and forms a class of salts called *columbates*.

CLASS 3. *Combustible Acids.*

The acids belonging to this class may be distinguished by the following properties.

1. If they be combined with potash, and distilled, they are decomposed, charcoal is usually evolved, and a considerable quantity of heavy inflammable air extricated.

2. All of them contain at least 2 simple combustibles as a base, namely *carbon* and *hydrogen*. Some of them also contain *azote*. Oxygen usually enters into their composition, though not perhaps always.

3. They do not seem capable of combining with different doses of oxygen. Whenever the proportion of oxygen changes, that of the other constituents varies also.

4. They are decomposed by the action of the more powerful acid supporters, and either converted into other combustible acids, or into oxide and acid products.

They may be divided into four orders. Those belonging to the first crystallize, and may be volatilized without decomposition. Those belonging to the second likewise crystallize, but they cannot be volatilized without decomposition. Those belonging to the third order are not crystallizable, though they may be exhibited in the state of a dry mass. Under the fourth order are placed three acids, which, from the singularity of their properties, ought to be considered apart.

The following table exhibits the names and component parts of each of these acids, as far as is known at present.

Order I. *Crystallizable, volatilizable.*

Names.	*Constituents.*
1. Acetic.	carbon, hydrogen, oxygen.
2. Benzoic.	
3. Sebacic,	
4. Succinic.	
5. Moroxylic	
6. Camphoric.	
7. Oxalic ?	

Order II. *Crystallizible, not volatilizable.*

1. Mellitic.	carbon, hydrogen, oxygen.
2. Tartaric.	
3. Citric.	
4. Kinic.	
5. Saclactic.	
6. Uric.	carbon, hydrogen, azote, oxygen.

Order III. *Not crystallizable.*

1. Malic.	Carbon, hydrogen, oxygen.
2. Suberic.	
3. Formic.	

Order IV. *Colorific.*

1. Prussic.	carbon, hydrogen, azote.
2. Gallic. 3. Tannin.	carbon, hydrogen, oxygen.

Sect. I. *Of Acetic Acid.*

This has been the longest known of all the acids. It obtained by causing *wine* or *beer* to undergo a new ferme tation. They become sour, and are known by the name *vinegar*. When the vinegar is distilled, a transparent colourless liquid is obtained, called *distilled vinegar*, or sometimes *acetous acid*. When this substance is combined with oxide of copper, and the dry mass distilled, a liquid is obtained, which contains the acid in a much more concentrated state. It was formerly called *radical vinegar*, and *acetic acid*, by way of eminence.

It is now known that the acid principle in all these three liquids is precisely the same, and that they differ merely in the concentration of that acid, or in consequence of containing small quantities of some foreign ingredient. Hence the term *acetic acid* is now applied to the acid in all cases.

Acetic acid is a liquid transparent and colourless like water. It has a peculiar and well-known aromatic smell when in the state of vinegar or distilled vinegar. In radical vinegar this smell is not so agreeable, being mixed with a kind of empyreumatic odour. When sufficiently concentrated, it may be obtained in crystals, but the process is difficult, and requires particular precautions to ensure success.

The specific gravity of distilled vinegar varies from 1·007 to 1·0095: that of radical vinegar is 1·080. But the strength of the acid is not always proportional to its specific gravity, owing to the presence of foreign bodies from which it is very difficult to free it. It is very volatile, unites with water in any proportion, and reddens vegetable blues.

Neither oxygen, the simple combustibles or incombustibles, have any action on this acid. It oxidizes some metals; but its action on these bodies is not violent. It combines with metallic oxides, and forms with every one a soluble salt. Indeed all the salts that contain acetic acid are soluble in water. In this respect it agrees with nitric acid.

It combines with salifiable bases, and forms a class of salts called *acetates*.

Sulphuric and nitric acids seem capable of decomposing it, but the action of the other acids is not remarkable. It dissolves and combines with many vegetable bodies, and is, in consequence, useful in vegetable analysis.

It is composed of oxygen, hydrogen and carbon, but the proportion of these constituents has not been hitherto ascertained in an unexceptionable manner.

SECT. II. *Of Benzoic Acid.*

This acid is obtained, by sublimation, from a resinous substance called benzoin.

It is a fine light white matter in small needles. It is not brittle, but has a kind of ductility. Its taste is acrid, hot, and somewhat bitter. Its odour is weak but aromatic. Its specific gravity 0·667. It reddens the most delicate vegetable blues.

It is easily volatilized by heat. It burns when kindled, and leaves no residuum. It is not altered by exposure to the air. Cold water dissolves no sensible quantity of it, but it dissolves readily in hot water.

It is not acted upon by oxygen gas, or by any of the simple combustibles or incombustibles; nor does it seem capable of oxidizing any of the metals.

It combines with the salifiable bases, and forms a class of salts called *benzoates.*

Several of the strong acids dissolve it; but it is precipitated again unaltered by the infusion of water. Alcohol dissolves it copiously.

SECT. III. *Of Sebacic Acid.*

This acid was mentioned many years ago, but its nature and properties remained unknown till it was lately examined by Thenard. Berzelius has lately added considerably to our knowledge of it. It may be prepared by the following process.

Distil hog's lard; wash the product with hot water, separate this water and drop into it acetate of lead. A flaky precipitate appears which is to be washed and dried, mixed with sulphuric acid and heated. A melted substance, like fat, swims on the surface. This substance is sebacic acid.

Sebacic acid is white, it has no smell; its taste is a pleasant sour, leaving in the mouth a very slight impression of bitterness. It reddens vegetable blues. When heated it melts like tallow, and, on cooling, concretes into a crystallized mass. It may be volatilized, but requires a higher temperature than benzoic acid. Berzelius has shown that this acid, in most of its properties, coincides with benzoic acid; and that the two acids, if not absolutely the same, at least approach very closely to each other.

SECT. IV. *Of Succinic Acid.*

This acid is obtained when amber is exposed to heat. It sublimes in small needles, coloured by an oil, from which it may be freed by digestion in nitric acid and subsequent crystallization. Trommsdorf affirms, that when dry saclactic acid is distilled, it yields abundance of succinic acid.

This acid is white, crystallizes in triangular prisms, has an acid taste, and reddens vegetable blues. When heated, it melts and then sublimes.

It is but little soluble in cold, but very soluble in hot water. Alcohol acts nearly upon it as water. It dissolves in sulphuric, nitric and muriatic acids, without undergoing decomposition.

It combines with the salifiable bases, and forms a class of salts called *succinates*.

SECT. V. *Of Moroxylic Acid.*

This acid was discovered by Klaproth in a saline exudation incrusting the bark of the white mulberry tree. This salt was a compound of the acid in question and lime.

The acid was separated by dissolving the salt in water, and precipitating the acid by means of acetate of lead. The precipitate was mixed with diluted sulphuric acid and digested. Sulphate of lead was formed and moroxylic acid disengaged. It crystallized in needles, which had the taste of succinic acid, were not altered by exposure to the air, and dissolved readily in water and in alcohol. When heated it sublimes, and thus may be obtained quite pure.

SECT. VI. *Of Camphoric Acid.*

This acid was discovered by Kozegarten, but first accurately described by Bouillon La Grange.

It is obtained by distilling a solution of camphor in nitric acid, repeatedly adding nitric acid till it amounts to 24 times the weight of the camphor. Crystals gradually make their appearance, which consist of *camphoric acid.*

This acid is snow-white. Its crystals are parallelopipeds which effloresce in the air. Its taste is acid and bitter, it has the smell of saffron, and reddens vegetable blues.

It dissolves in about 100 parts of cold water, but is more soluble in hot water. It dissolves in alcohol. The salts which it forms are called *camphorates.*

SECT. VII. *Of Oxalic Acid.*

This acid was discovered by Scheele, and first described by Bergman. It is obtained by heating a solution of sugar in nitric acid.

It crystallizes in small four-sided prisms, terminated by dihedral summits. These crystals are composed of 77 parts acid and 23 water. When exposed to heat it sublimes, but at the same time is partly decomposed.

These crystals have a very acid taste, and redden vegetable blues. They dissolve in their own weight of boiling water, and in twice their weight of cold water. They dissolve, also, readily in alcohol.

When exposed to dry air they effloresce; but in moist air they are not altered. Neither oxygen, nor the simple combustibles or incombustibles act on this acid. It oxidizes some of the metals; but most of them are not affected by it.

It combines with the salifiable bases, and forms a class of salts called *oxalates*.

Muriatic and acetic acids dissolve it, sulphuric acid decomposes it by the assistance of heat. Nitric acid converts it into water and carbonic acid.

When combined with a base and distilled, it is decomposed and converted into *water*, *carbonic acid*, *carbonic oxide*, *carbureted hydrogen*, and *charcoal*. It is composed, according to my experiments, of

oxygen	64
carbon	32
hydrogen	4
	100

SECT. VIII. *Of Mellitic Acid.*

This acid was discovered by Klaproth, in the mineral called *mellite* or *honeystone*, which he found composed of alumina and the acid in question.

It is obtained by boiling the mineral powder in 72 times its weight of water, filtering the liquid and evaporating sufficiently. The mellitic acid crystallizes.

The crystals are needles, having a brownish colour, and a sweetish sour taste. It is but moderately soluble in water. Nitric acid does not seem to decompose it. It reddens vegetable blues. The salts which it forms are called *mellates*.

SECT. IX. *Of Tartaric Acid.*

This acid exists in the salt called *tartar*, from which it was first obtained in a separate state by Scheele. The process is this:

Dissolve tartar in water, and add chalk in powder as long as an effervescence continues. A white powder precipitates. Pour on this precipitate a quantity of sulphuric acid equal in weight to the chalk employed, previously diluted with water, and digest for a day or two. Then filter and evaporate the liquid. The tartaric acid is obtained in crystals.

These crystals are white, transparent and hard. They are very irregular four-sided prisms, composed of 84·5 real acid, and 15·5 water.

It is not altered by exposure to the air. At 212°, it melts and becomes as liquid as water. At 250°, it boils without losing its transparency or acquiring colour. When cooled it concretes into a hard mass, but the nature of the acid is changed. It has now acquired the property of deliquescing when exposed to the air. When distilled, this acid yields an acid liquid formerly called pyrotartarous acid, but now known to be the acetic disguised by means of an emypreumatic oil. When combined with a base and distilled, tartaric acid is decomposed and converted into *water, carbonic acid, heavy inflammable air,* and *charcoal.*

It dissolves readily in water, and when the solution is diluted, the acid undergoes spontaneous decomposition.

None of the simple substances produce any striking effect upon this acid. It combines with the salifiable bases, and forms a class of salts called *tartrates.*

SECT. X. *Of Citric Acid.*

This acid exists in the juice of oranges and lemons, and was first obtained pure by Scheele. His process was this:

Saturate lemon-juice with chalk. A precipitate falls. Wash this precipitate, and pour on it as much sulphuric acid as will saturate the chalk employed, previously diluted with six times its weight of water. Digest, filter and evaporate the liquid. The citric acid crystallizes.

This acid crystallizes in rhomboidal prisms. The crystals are not altered by exposure to the air. The taste is acid, and vegetable blues are reddened by it. It dissolves in less than its weight of water.

It is not acted on by the simple substances. It oxidizes a few of the metals. It combines with the salifiable bases, and forms a class of salts called *citrates*.

Sulphuric acid decomposes it. Nitric acid converts it into oxalic acid, or into acetic acid, if used in excess.

SECT. XI. *Of Kinic Acid.*

This acid was discovered by Vauquelin, in a salt first obtained from *Jesuits bark*, by Deschamps. This salt is a compound of kinic acid and lime.

Vauquelin dissolved the salt in water, and precipitated the lime by means of oxalic acid. The liquid was evaporated to the consistence of a syrup, and then set aside. No crystals formed in it at first, but on being touched, it wholly crystallized in diverging plates.

Its colour is somewhat brown, its taste very acid and bitter. It was not altered by exposure to the air. It is very soluble in water. It does not precipitate silver nor lead from their solutions. When heated it is decomposed, and charcoal remains behind.

SECT. XII. *Of Saclactic Acid.*

This acid was discovered by Scheele, who formed it by digesting sugar of milk in nitric acid. Fourcroy and Vauquelin ascertained, afterwards, that it is formed when gum is heated with nitric acid and the solution allowed to cool. A white powder precipitates, which is the acid in question.

Saclactic acid, thus obtained, is in the form of a white gritty powder, with a slight acid taste. It is only slightly soluble in boiling water. The solution has an acid taste, and reddens vegetable blues.

The compounds which this acid forms, with the salifiable bases, are called *saccolates.*

SECT. XIII. *Of Uric Acid.*

This acid was discovered by Scheele in urinary calculi, and first called *lithic acid.* But this term was afterwards laid aside, and *uric acid* substituted; because this acid constitutes one of the ingredients of urine. For the best account of the properties of this acid we are indebted to Dr Henry.

It is obtained by dissolving the calculi, composed chiefly of it, in alkaline ley, and precipitating by means of muriatic or acetic acids. The white powder which falls, when well edulcorated, is pure uric acid.

It is a white powder, without taste or smell. It reddens vegetable blues, and requires more than 1700 parts of cold water to dissolve it.

It dissolves readily in fixed alkaline solutions; but not in alkaline carbonates. It dissolves in nitric acid, and when the solution is evaporated nearly to dryness, it assumes a fine pink colour, which becomes much deeper when water is added, so as to have a near resemblance to carmine. The watery solution of this matter loses its red colour in a few hours, and it cannot afterwards be restored.

Oxymuriatic acid readily converts the uric into the oxalic acid.

When distilled, carbonate of ammonia is obtained, and a saline sublimate, which Dr Henry has shown to be a compound of ammonia with a peculiar acid.

SECT. XIV. *Of Malic Acid.*

This acid was discovered by Scheele. It exists in apples, and in a variety of vegetable substances. It is formed also by the action of nitric acid on sugar.

Scheele obtained it by saturating the juice of apples with potash, precipitating by acetate of lead, digesting the precipitate in a sufficient quantity of sulphuric acid to separate the lead, and then filtrating. The liquid contained pure malic acid.

When malic acid is obtained by the action of nitric acid on sugar, it is colourless; but it very easily acquires a brown colour by the action of heat, or even by keeping it in a liquid state. When evaporated, it may be obtained in a solid state; but it is not capable of crystallizing. Its taste is very acid, and it dissolves readily in water. It is said to undergo spontaneous decomposition; but I have kept it more than two years in a liquid state without observing any such change. It bears a strong resemblance to the citric acid, but it does not crystallize, forms a more soluble salt with lime, and precipitates mercury, lead and silver from nitric acid, which citric acid does not.

The compounds which it forms with the salifiable bases, are called *malates*.

SECT. XV. *Of Suberic Acid.*

This acid was obtained by Brugnatelli by digesting common cork in nitric acid. Its properties were afterwards more investigated by Bouillon La Grange.

It does not crystallize; but may be obtained in powder or in pellicles. Its taste is acrid and slightly bitter, it reddens vegetable blues, attracts moisture when exposed to the air, but is not very soluble in water. It may be sublimed without decomposition. The other acids dissolve it incompletely. The salts which it forms are called *suberates*.

SECT. XVI. *Of Formic Acid.*

This acid exists in the *formica rufa*, or *red ant*. It was noticed in a paper by Mr Ray in 1671, in consequence of the observations of Halse and Fisher. But its properties were first investigated by Margraff. Fourcroy and Vauquelin endeavoured to prove that it was a mixture of *acetic* and *malic acids;* but the experiments of Suersen have shown that this opinion is not correct.

This acid may be obtained by infusing the ants in water, distilling off the water as long as it comes over without any burnt smell, saturating the water with potash, evaporating to dryness, mixing the residue with as much diluted sulphuric acid as is sufficient to saturate the potash employed, distilling this mixture to dryness, rectifying the liquid that comes over by a second distillation with a moderate heat. The liquid now contains only pure formic acid.

This liquid is colourless like water. It has a peculiar smell; it reddens vegetable blues, and has an acid taste. Its specific gravity varies from 1·102 to 1·113, whereas the most concentrated acetic acid is only 1·080. Notwithstanding this superior weight, it is not capable of neutralizing so much of the salifiable bases as acetic acid. Lowitz attempted, in vain, to procure this acid in crystals, though he succeeded easily with acetic acid. The compounds which it forms with the different bases are called *formates*. There is a striking analogy between them and the *acetates*.

CHAP. III.

OF COLORIFIC ACIDS.

Under this name I include three substances which possess such peculiar properties that they ought to be considered separately from the combustible acids. These are *prussic acid*, *gallic acid* and *tannin*. The two first have always been considered as acids. The last, though not acid, is so intimately connected with the gallic, that they cannot well be separated. These substances possess the following characters.

1. They unite with alkaline bodies, but do not seem capable of neutralizing them.

2. They act with great energy upon metallic solutions, usually entering into combination with the oxide, and precipitating it in the state of an insoluble powder.

3. They have a tendency to enter into triple compounds with a variety of bodies, especially with metallic oxides and alkalies.

SECT. I. *Of Prussic Acid.*

This important substance was accidentally discovered by a chemist of Berlin in 1710. This chemist, Diesbach by name, found out the method of preparing *prussian blue.* The nature of this pigment was examined by Brown. But it was Macquer who first ascertained its nature in a satisfactory manner. In consequence of his experiments, prussian blue was considered as a compound of oxide of iron with a peculiar acid. But no one was able to obtain this acid in a separate state, or to ascertain its properties, till Scheele, in two admirable dissertations published in 1782 and 1783, pointed out a method of procuring it, and gave a detailed account of its nature.

He procured the prussic acid in the following manner. He boiled in a matrass a mixture of 10 parts prussian blue, 5 parts red oxide of mercury, and 30 parts of water, and filtered the solution. The liquid was poured upon 2½ parts of clean iron filings, and at the same time 1 part of sulphuric acid was added and the mixture shaken. The iron disappeared and a quantity of running mercury was precipitated in its place. Distil off one-fourth of this liquid by a moderate heat, what comes over consists of water holding prussic acid in solution.

Prussic acid, thus obtained, is a colourless liquid like water. It has a strong odour resembling that of the flowers of the peach or of bitter almonds. Its taste is sweetish, acrid and hot, and it is apt to excite cough. It does not alter the colour of vegetable blues. When swallowed it proves a very virulent poison.

It is very volatile, and evidently capable of assuming the gaseous form, though hitherto it has scarcely been examined in that state.

It is capable, when dry, of withstanding a red heat without decomposition, but when water is present, it very readily undergoes change.

It combines with the salifiable bases, and forms a class of bodies called *prussiates.* But they have very little permanency, being decomposed by all other acids, and even by exposure to the atmosphere.

It is capable also of forming triple compounds, in which it is combined with two bases at once, one of them an alkali or earth, the other a metallic oxide. These compounds are much more permanent, and are therefore usually employed by chemists. The one in most frequent use is the *triple prussiate of potash,* a yellow coloured salt crystallizing in cubes, and composed of prussic acid, potash and oxide of iron.

Scheele succeeded in forming prussic acid by causing a current of ammoniacal gas to pass through red hot charcoal, and the experiment has been since repeated successfully by others. Hence it is obvious, that this acid is composed of the constituents of ammonia and charcoal united together, or of hydrogen, azote and carbon. This has been further confirmed by Berthollet. Oxymuriatic acid has the property of altering the nature of prussic acid, and renders it capable of throwing down iron from solutions *green* instead of blue. To the acid thus altered, Berthollet gave the name of *oxyprussic acid.* When heat is applied to it, the whole is converted into carbonate of ammonia.

Prussian blue may be formed by calcining a mixture of potash and dried blood in a covered crucible in a heat gradually raised to redness. The mass is dissolved in water, and poured into a solution of sulphate of iron. A green coloured precipitate falls, which becomes prussian blue when digested in muriatic acid. The triple prussiate of potash was formerly called phlogisticated alkali. It is still useful in detecting different metals in solutions by the colour of the precipitate which it occasions, especially iron, which it throws down of a deep blue.

SECT. II. *Of Gallic Acid.*

This acid forms one of the constituents of the substance called *nutgalls*, a concretion formed on the oak in consequence of the puncture of insects. Nutgalls come to this country chiefly from the Levant. They vary a good deal in their appearance. Scheele first separated gallic acid from nutgalls. An infusion of nutgalls left to itself for some time becomes mouldy on the surface, and lets fall small crystals. These crystals being picked out, dissolved in water, and obtained again by evaporation, constitute *gallic acid*.

The acid obtained by this procees is never quite pure. If the infusion of nutgalls' be evaporated to dryness, and the powdered residue be digested in pure alcohol, the alcohol, when cautiously distilled to 1-8th, leaves a residue behind it nearly colourless, which is soluble in water, and yields by evaporation gallic acid in needles much lighter coloured and purer than that obtained by the first described process.

Gallic acid is white, usually with a shade of brown or yellow. It is crystallized in needles or transparent plates. Its taste is acid and somewhat astringent, and when heated, it exhales a peculiar, and rather unpleasant aromatic odour. It is soluble in 1½ parts of boiling, and in 12 parts of cold water. When the solution is heated, the acid is decomposed. When long kept, it becomes darker coloured, and the acid is likewise altered in its properties.

When heated, it sublimes, but its properties are somewhat altered. When distilled, it yields, like other vegetable acids, carbonic acid gas, and heavy inflammable air. Water is also formed, and a portion of the acid escapes slightly modified in its nature.

It is not altered by exposure to the air. Neither oxygen gas, the simple combustibles or incombustibles seem to produce any effect upon it. The action of the metals is unknown.

The compounds of this acid, with the salifiable bases, are called *gallates*. They have scarcely been examined. When gallic acid is dropt into lime, barytes or strontian water, it strikes a bluish red colour, and occasions a flaky precipitate. It occasions a precipitate likewise when poured into the solutions of yttria, glucina or zirconia in acids. Upon metallic solutions it acts with considerable energy, changing their colour, and occasioning precipitates in many of them. Thus, with iron it strikes a dark blue, or almost black colour. When it precipitates metallic oxides, it seems to bring them nearer to the metallic state, and sometimes reduces them altogether. Thus gold is precipitated by it in the metallic state.

SECT. III. *Of Tannin.*

Nutgalls, besides gallic acid, contain several constituents, one of the most curious and important of these is tannin, which is to occupy our attention in this section.

Tannin was first pointed out in vegetables by Deyeux, though some of its properties had been noticed long before by Lewis. Seguin first pointed out its great importance in tanning, and hence the name was given it, by which it is at present known. Proust endeavoured to obtain it in a separate state. Mr Davy added to our knowledge of its properties. But it is to Mr Hatchet that we are indebted for the most important set of new facts. He pointed out a method of making it artificially from almost all animal and vegetable substances. As Mr Hatchet's tannins differs in several respects from the tannin of nutgalls and other astringent substances, it will be proper to divide this section into two parts.

1. *Natural Tannin.*

No unexceptionable method of obtaining tannin from nut-galls, in a state of complete purity, has yet been discovered. The best method is this:

Make an infusion of nut-galls in water, evaporate the infusion to dryness, pulverize the residuum and digest the powder in repeated portions of pure alcohol till that liquid ceases to dissolve any thing. The residue is tannin tolerably pure. It may be dissolved in water and precipitated by acetate of lead. The edulcorated precipitate being mixed with water, and a current of sulphureted hydrogen passed through it, the lead combines with sulphur and remains insoluble; while the tannin, thus set at liberty, dissolves in the water and may be obtained by evaporating the liquid.

Tannin, thus obtained, is a brittle substance of a brown colour, with an astringent taste like that of nut-galls. It dissolves readily in water, and the solution, according to Trommsdorf, is not liable to become mouldy. Pure alcohol does not dissolve it; but it is soluble in alcohol diluted with a little water, as for example in alcohol of 0·818 of specific gravity, which contains 1-10th of its weight of water.

It seems capable of combining with oxygen, but its properties are, by that means, completely altered; being, according to Proust, a species of *extractive.*

The action of the simple combustibles on tannin is unknown. The action of the metals is probably small, but it combines with most of the metallic oxides, and forms compounds which, for the most part, are insoluble in water. Thus it strikes a deep blue or black with solutions of iron, and if the solutions be diluted, the compound of tannin and the oxide of iron precipitates.

When a solution of *glue*, or *gelatine* as chemists term it, is poured into an aqueous solution, a precipitate immediately falls. This precipitate consists of tannin and gelatine combined together. It is insoluble in water, and composed, according to Davy, of 54 gelatine and 46 tannin. This property renders gelatine a very delicate test of tannin, which it detects when it exists, even in small proportion, in vegetable liquids.

The alkalies combine with tannin, and prevent it from precipitating gelatine till they are saturated with an acid.

The earths combine with tannin and form with it compounds nearly insoluble. Hence they precipitate it from the infusion of nut-galls.

Most of the acids combine with tannin, and form soluble compounds with it. Arsenic, muriatic and sulphuric acids precipitate it from water. The sulphuric acid gradually decomposes it. Nitric acid also decomposes it, and a substance is formed having the properties of malic acid.

Such are the properties of the tannin of nut-galls, as far as they have been ascertained. The difficulty of obtaining it in a state of purity renders some of them ambiguous, and has induced chemists to employ the infusion of nut-galls in their experiments rather than tannin.

This infusion is employed in considerable quantity by dyers, and it forms the principal ingredient of common *writing ink*. This liquor consists of a solution of sulphate of iron in the infusion of nut-galls. No other salt of iron tried answers so well as the sulphate. The deepest black is formed when equal weights of nut-galls and of sulphate of iron are employed. But it is not permanent unless the nut-galls amount to about thrice the weight of the sulphate. The best ink, according to Dr Lewis, who made many experiments on the subject, may be made by means of the following formula.

Logwood,	1 ounce.
Nut-galls, in powder,	3
Green vitriol,	1
Water,	1 or 2 quarts.

Boil the logwood and the nut-galls in water, adding new liquid in proportion to the evaporation, then strain through a cloth and dissolve the green vitriol, adding at the same time one ounce of gum arabic and a little sugar. Some recommend the addition of a little cloves to prevent the ink from moulding.

Tannin exists in many other substances besides nut-galls. The barks of many trees, the substances called catechu and kino, logwood, brazil wood, fustick and many other vegetable bodies yield it in abundance. From the experiments of Proust, it appears that it varies in its qualities in these bodies, or that there are different species of tannin varying from each other in several respects, especially in the colour which they strike with iron. Some precipitate that metal black, some green, and some flesh-red.

2. *Artificial Tannin.*

The important discovery, that a substance capable of tanning leather like the tannin of nut-galls, may be formed artificially, was made by Mr Hatchett in the course of a set of experiments on the slow carbonization of vegetable bodies, and detailed by him in various papers read to the Royal Society in 1805.

To form it, we have only to digest diluted nitric acid on charcoal, till the whole, or nearly the whole, is dissolved, and evaporate the solution to dryness; a brown coloured matter remains, which is *artificial tannin.* 100 grains of charcoal, by this process, were converted into 120 grains of artificial tannin. A part of this increase is moisture, and it is very difficult to get rid of the whole of the nitric acid, a portion of which adheres to the tannin with great obstinacy.

Tannin, thus prepared, is a substance of a brown colour, it has considerable lustre, and breaks with a vitreous fracture. Its taste is very bitter and highly astringent. It has no smell. It dissolves readily in cold water, forming a brown coloured solution. Alcohol, of the specific gravity 0·800, also dissolves it.

The solution is precipitated by gelatine very readily. The precipitate is brown, and composed, according to Hatchett, of 36 tannin and 64 gelatine.

Sulphuric and muriatic acids form a precipitate when poured into solutions of artificial tannin. Nitric acid does not decompose it nor alter its properties. This forms a marked distinction between natural and artificial tannin.

The alkalies unite with it, and prevent it from precipitating gelatine till they are saturated. The alkaline earths, and most of the metallic oxides form insoluble compounds with it. Hence it precipitates most of these bodies from their solutions.

When distilled, artificial tannin yields water, a little nitric acid, and a yellow coloured liquid; on raising the fire, ammoniacal gas is disengaged with great rapidity, this is followed by carbonic acid gas, and a gas possessing the properties of azote. A bulky charcoal remains behind. From these results it is obvious that this substance consists of oxygen, azote, hydrogen and carbon. The last constituent, no doubt, predominates.

Mr Hatchett has shown that every charcoal, both from animal and vegetable substances, provided it be in the state of charcoal, yields artificial tannin when digested with nitric acid. He has pointed out two other methods of procuring a substance possessed of similar properties. The first is by dissolving indigo and the resins or gum resins in nitric acid, and digesting them for a considerable time in that liquid. When the solution is evaporated to dryness, a yellow coloured matter remains, which possesses the properties of artificial tannin. The second method is by dissolving camphor and the resins in sulphuric acid, digesting till the solution becomes black, and then precipitating by pouring it into cold water. If the black powder which falls be digested in alcohol, a brown matter is taken up which possesses many of the properties of artificial tannin.

Such are the properties of the colorific acids. They act with most energy on metallic solutions, forming precipitates which vary in their colour according to the metal. It is this property which renders them of so much importance in a chemical point of view. The following table exhibits a view of the colours which these bodies strike with the different metals, as far as is known.

	Prussiate of Potash.	*Gallic Acid.*	*Infusion of Nut-galls.*	*Artificial Tannin.*
Gold	Yellowish white	Reduced	Reduced	Reduced
Platinum	0	0	0	
Silver	White	Yellowish brown	Yellowish brown	Yellow
Mercury	White	Orange yellow	Orange yellow	Yellow
Palladium	Olive			
Rhodium	0			
Iridium	0 Becomes colourless		0 Becomes colourless	
Osmium			Blue	

	Prussiate of Potash.	*Gallic Acid.*	*Infusion of Nut-galls.*	*Artificial Tannin.*
Copper	Greenish yellow	Brown	0 Becomes olive	Olive
Iron	Blue	Black	Black	Brown
Nickel	Green	White	Grey	
Tin	White	0	Brown	Blackishgrey
Lead	White	White	White	Brown
Zinc	White	0	0	0
Bismuth	White	Orange	Orange	
Antimony	0	White	White	Yellow
Tellurium	0		Yellow	
Arsenic	White	0	0	Yellow?
Cobalt	Brown yellow	0	Yellow white	
Manganese	Yellow white	0		
Chromium	Green		Brown	
Molybdenum				
Uranium	Brown red		Chocolate	
Tungsten	Brown		Straw yellow	
Titanium	Yellowis. brown		Blood red	
Columbium	Olive		Orange	
Cerium	White	0	0	

CHAP. IV.

[illegible] COMBUSTIBLES.

[illegible] combustibles are usually composed of car- [illegible] hydrogen and oxygen. [illegible] elements. [illegible] almost all the animal and [illegible] progress of the investigation of [illegible] importance in chemical investigations, [illegible] warrant their introduction here. [illegible] shall de- [illegible] compound combustibles which are of im- [illegible] reagents or chemical analysis. These may be [illegible] the following heads. [illegible] Alcohol. [illegible] Bitumens.

[illegible]

[illegible] is obtained [illegible] fermented liquors are subjected to [illegible] were unacquainted with it. We [illegible] this fluid, but it was known [illegible] introduced by them into pharmaceuti- [illegible]

[illegible] distillation of fermented liquors that ardent [illegible] and they receive various names according [illegible] substance employed. Thus *brandy* is [illegible] from the fermented juice of the *su-* [illegible] from the fermented infusion of *malt* [illegible] ardent spirits consist almost entirely of 3 [illegible] water, pure spirit or alcohol, and a little [illegible] which they owe their flavour and colour. [illegible] liquids are re-distilled, the first portion that omes over is a fine light transparent liquid, known in commerce by the name of *rectified spirits*. When as highly rectified as possible, the specific gravity of the liquid obtained loes not appear to be less than 0·820, and is generally more. Alcohol, by this process, cannot be deprived of the whole of he water with which it is combined. The best method of etting rid of the water is to expose a quantity of the salt alled *muriate of lime* to a red heat, to put it into a retort while still warm, and to pour over it a portion of alcohol of bout 0·820, nearly equal to it in weight. The alcohol dissolves the salt, and much heat is evolved. This mixture is o be exposed to heat and the alcohol distilled off. The salt etains the water, and the alcohol comes over of the specific ravity 0·791 at 68°, or 0·796 at 60°. In this state it is the trongest alcohol that can be procured. It is, therefore, alled *pure*, or *absolute alcohol*. The alcohol of commerce s never so strong as this, its specific gravity is seldom under 0·837.

Alcohol, thus procured, is a transparent liquid, colourless as water, of a pleasant smell and a strong penetrating agreeable taste. When swallowed it produces intoxication. It cannot be frozen in the greatest degree of cold to which it has been exposed, and it has been cooled down in thermometer tubes to —91°. It is very volatile, evaporating spontaneously at the common temperature of the atmosphere. When heated to 173½° it boils, and is converted into an elastic fluid, possessing the mechanical properties of air, but more than twice as heavy.

It combines with water in every proportion, and forms spirits of different degrees of strength according to the quantity of water present. The common spirits of commerce are nothing else than such combinations of alcohol and water. The proportion of alcohol present in these liquids is best judged of by their specific gravity. The specific gravity of pure alcohol is 0·796. That of water 1·000. Hence the lighter a spirit is the stronger is it. Alcohol of 0·820 contains nearly 1-10th of its weight of water; alcohol of 0·840 contains $\frac{17}{100}$ parts of water. What, in this country, is called *proof spirits*, is of the specific gravity 0·920. It was understood to be a mixture of equal bulks of alcohol and water. This however is not the case. It contains 0·52 of its weight of water. When spirits are weaker than 0·920, they are said to be *under proof*; when stronger, to be *above proof*. The spirits retailed in Scotland are, almost always, under proof, and sometimes indeed very weak.

Neither common air nor oxygen gas act upon alcohol at the common temperature, but in high temperatures the case is different. When alcohol is kindled in the open air, it burns all away without leaving any residuum. The flame is blue, and if the vapours emitted be collected, they are found to consist of carbonic acid and water, and the portion of water formed is greater than the whole of the alcohol consumed. When the vapour of alcohol is mixed with oxygen gas, it may be kindled by an electric spark, provided the temperature be above 70°, a detonation takes place, the alcohol is consumed and water and carbonic acid formed. When alcohol is passed, in the state of vapour, through a red-hot porcelain or metallic tube, it is decomposed and a variety of new products evolved. These are, 1. a great quantity of inflammable air, which, according to Saussure junior, consists of oxygen, hydrogen, carbon, and azote; 2. A little charcoal; 3. A little oil, partly in crystals, partly fluid; 4. A portion of water holding, in solution, traces of acetic acid and ammonia; 5. A little of an acid which resembles the benzoic. By estimating the proportions of ingredients formed in these decompositions, chemists have endeavoured to ascertain the constituents of alcohol. The following is the result obtained by Saussure junior, who has lately published an elaborate set of experiments on the constituents of alcohol. It is composed of

Oxygen, ...	37·85
Carbon, ...	43·65
Hydrogen, ...	14·94
Azote, ...	3·52
Ashes, ...	0·04
	100·00

Alcohol has little action on the simple combustibles. On hydrogen and charcoal it seems to produce no effect. But it dissolves a little phosphorus and sulphur. If phosphureted alcohol be dropt into water, a lambent flame is observed playing on the surface of the liquid, and the phosphorus is disengaged.

Alcohol dissolves the fixed alkalies. It is by means of it, indeed, that these bodies are obtained in a state of purity. The earths are scarcely acted on by alcohol. It absorbs a quantity of nitrous gas, which cannot afterwards be expelled by heat.

The strong acids decompose alcohol. The rest combine with it, and form a set of compounds hitherto but little examined. It dissolves also a considerable number of salts, especially the acetates, muriates and nitrates. The sulphates are all insoluble in it. The colour of the flame of alcohol is tinged by various bodies. Thus nitrate of strontian tinges it purple; boracic acid and the cupreous salts tinge it green; muriate of lime gives it a light red colour; nitre and oxymuriate of mercury a yellow colour.

SECT. II. *Of Ethers.*

When alcohol is acted upon by several of the acids, a fragrant liquid is formed, to which the name of *ether* has been given. These ethers are named from the acid employed in forming them. As they differ in their properties, it will be requisite to describe them separately.

1. *Sulphuric Ether.*

This liquid was known about the end of the 15th century, and some of its properties were described by Boyle; but the attention of chemists was first drawn to it by a paper published in the Philosophical Transactions for 1730, by a German who called himself Dr Frobenius.

It may be obtained by distilling a mixture of equal parts of alcohol and sulphuric acid in a glass retort, to which a large receiver is attached. The ether condenses in the receiver. When first prepared it contains some sulphurous acid, which is removed by putting some powdered chalk into it, and agitating repeatedly in a close phial, till the sulphurous acid smell is dissipated. The ether is then distilled a second time. It still retains a portion of alcohol from which it may be freed by adding to it dry muriate of lime as long as it will dissolve that dry salt, and leaving the solution in a well corked phial. The muriate of lime dissolved in the alcohol gradually subsides, and the pure ether floats on the top. It may be decanted off.

Ether thus obtained is a limpid and colourless fluid like water. It has a peculiar and agreable smell, and a hot pungent taste. Its specific gravity when pure is only 0·632 at 60°; but the ether of commerce is seldom lower than 0.775, owing to the alcohol which it contains.

It is so volatile that it cannot be poured from one vessel to another without considerable loss. When exposed to the open air, it disappears in a very short time. It boils at 98°, and in a vacuum at —20°. When evaporated, it produces a considerable degree of cold, so that water may be easily frozen by means of it even in summer. The specific gravity of the vapour of ether, according to Dalton, is 2·25, that of air being 1·00. When ether is exposed to a cold of —46°, it freezes and crystallizes.

Neither oxygen gas nor air produce any effect upon ether at the common temperature of the atmosphere; but when kindled in contact with these fluids, it burns with a strong white flame, giving out a great deal of light and heat. The products in this case are carbonic acid and water. It consumes during its combustion about 7 times its bulk of oxygen, supposing the ether in the gaseous state. When mixed with oxygen gas in that proportion, it explodes very loudly when an electric spark is passed through the mixture. Various attempts have been made to estimate the constituents of ether by consuming it with oxygen gas, and ascertaining the products obtained. The following is the composition of ether, according to the experiments of Saussure, junior.

Carbon, . . .	58·20
Hydrogen, .	22·14
Oxygen, . . ·	19·66
	100·00

These numbers indicate a much greater proportion of carbon and hydrogen, and a much smaller proportion of oxygen in sulphuric ether than in alcohol.

When ether is passed through a red hot porcelain tube, it is decomposed and converted into oil, charcoal, water, and a great proportion of heavy inflammable gas.

Ether combines only in a small proportion with water.

Ten parts of that liquid dissolve about one part of ether. But alcohol unites with ether in any proportion.

Ether dissolves a little phosphorus and sulphur, but does not seem to act upon the other simple combustibles. It has no action on the metals, but revives those metallic oxides which readily part with their oxygen, as the oxides of gold and silver. It dissolves the muriate of gold, and the oxymuriate of mercury.

It does not appear to have any action on the alkalies or earths. It readily dissolves ammonia and nitrous gas.

Sulphuric acid seems capable of converting it into sweet oil of wine. Oxymuriatic acid sets it on fire spontaneously. The action of the other acids has not been ascertained.

It dissolves the fixed and volatile oils, and bitumens, but does not act upon gums.

From its constituents, as ascertained by Saussure, compared with those of alcohol, it is obvious that, during the formation of sulphuric ether, the alcohol is decomposed. This decomposition, according to Fourcroy and Vauquelin, is owing to the high temperature to which the alcohol is subjected in consequence of being prevented from evaporating so easily by the sulphuric acid with which it is combined.

2. *Nitric Ether.*

This ether is mentioned by some of the older chemists, but its properties were almost unknown till it was lately examined by Thenard.

It may be formed by distilling a mixture of equal parts of alcohol and nitric acid of the specific gravity 1·283 in a retort, from which passes a tube that goes to the bottom of a tall glass jar half filled with a saturated solution of common salt in water. Several of these jars are connected together by tubes, and from the last a tube passes to convey the gaseous products to the water trough. The ether condenses on the surface of the liquid in these jars. It contains at first a little nitrous and acetic acids, from which it is purified by agitation with chalk in a close phial till it ceases to redden vegetable blues.

Nitric ether thus prepared has a pale yellow colour, and a very strong etherial odour. Its taste is strong and quite peculiar. It is rather heavier than alcohol, but much more volatile than sulphuric ether. Hence it only moistens bodies for a moment, and produces a considerable cold by its evaporation. The heat of the hand is sufficient to make it boil.

It dissolves in 48 parts of water, and communicates to that liquid an odour like that of apples. It dissolves in alcohol in any proportion. It burns with a white flame, and as brilliantly as sulphuric ether. When kept for some time, both nitric and acetic acids are evolved in it. The same acids make their appearance if the ether be heated, or if it be agitated in water. When brought incontact with a little of these acids, it instantly absorbs them, and acquires the property of reddening vegetable blues.

At the temperature of 70°, it quintuples the bulk of gases. At that temperature its vapour is capable of supporting a column of mercury 28·74 inches high. Hence its boiling point is obviously only a degree or two above 70°.

From the analysis of Thenard, the constituents of nitric ether are as follows:

Oxygen, . . .	48·52
Carbon, . . .	28·45
Azote, ...	14·49
Hydrogen, . .	8·54
	100·00

It is probable that it contains nitric acid ready formed, as one of its constituents, and that this acid is neutralized by the spirit, and thus prevented from acting on vegetable blues. It is obvious from the preceding account of its properties, that nitric ether differs entirely from sulphuric ether in its nature.

3. *Muriatic Ether.*

After the discovery of sulphuric and nitric ether, various attempts were made to procure muriatic ether and different processes were suggested. Sometimes a mixture of alcohol, and those metallic muriates that contain an excess of acid were distilled, and sometimes alcohol was saturated with muriatic acid gas and distilled. The nature of muriatic ether was almost unknown till a set of experiments was made on it by Gehlen in 1804. Thenard made another in 1807. To the labours of these two chemists we are indebted for all the knowledge we possess of this singular fluid.

It may be obtained by distilling in a retort equal bulks of alcohol and muriatic acid, both as strong as possible. From the retort a tube passes into a Woulfe's bottle, partly filled with water, and from the bottle another tube passes into the water trough. The whole of the ether formed assumes the gaseous form if the temperature be as high as 70°, and may be collected in jars over water. A mixture of acid and alcohol weighing 30 ounces troy, yields more than 1200 cubic inches of this etherial gas.

This gas is colourless; it has a strong etherial smell, and a sweetish taste. It produces no change on vegetable blues or lime water. Its specific gravity is 2·219, that of air being 1·000. At the temperature of 64°, water absorbs its own bulk of this gas.

At the temperature of 52° it loses its gaseous form, and becomes liquid ether. It may be obtained in that state by passing it into a jar surrounded with ice. In its liquid state it is colourless like water, and has the same smell and taste as when gaseous. At the temperature of 41° its specific gravity is 0.874. It has no effect on vegetable blues. It is much more volatile than sulphuric or even nitric ether, assuming the gaseous form when not hotter than 64°. It burns with a green coloured flame, and a great quantity of muriatic acid is disengaged during the combustion. Thus it appears that muriatic acid is one of its constituents. But as the presence of that acid cannot be detected before combustion by the usual tests, it is obviously neutralized by the other constituents of the ether. Thenard has endeavoured to ascertain the constituents of this ether. The following are the proportions which he found:

Muriatic acid,	29·44
Carbon,	36·61
Oxygen,	23·31
Hydrogen,	10·64
	100·00

During the formation of muriatic ether, no gas whatever is evolved except the ether, and no new product appears except the ether itself. A portion of the muriatic acid disappears, and exactly the same portion makes its appearance again when the ether is burnt. These effects render it probable that muriatic ether is a combination of muriatic acid and alcohol. But if any dependence can be put in the above analysis, and in Saussure's analysis of alcohol, it is obvious that the alcohol in entering into the composition of muriatic ether has been altered, as its constituents are not in the same proportion as in pure alcohol.

4. *Acetic Ether.*

Acetic ether was discovered in 1759 by the Count de Lauraguais, who obtained it by distilling a mixture of alcohol and acetic acid. The process has been often repeated, and has been improved since its original discovery. Thenard has lately examined the properties of this ether.

He obtained it by distilling a mixture of strong acetic acid and alcohol in a retort, and repeating the distillation 12 times. No gas was found, nor any symptom of the decomposition of either of the substances used exhibited. He then saturated the acid with potash, and by distilling the liquid off acetate of potash, he got the ether in a separate state.

Acetic ether is limpid and colourless. It has an agreeable odour of ether and acetic acid. It has a peculiar taste bearing no resemblance to that of alcohol. It does not redden vegetable blues. At the temperature of 44½°, its specific gravity is 0·866. It boils at the temperature of 160°. It burns with a yellowish white flame, and acetic acid is developed. It undergoes no change by keeping. At the temperature of 62° it requires more than 7 times its weight of water to dissolve it. It seems from the preceding account to be a kind of combination of acetic acid and alcohol, substances which it seems have the property of neutralizing each other.

5. *Phosporic Ether.*

From the late experiments of Boullay, it appears that ether may be formed also by means of phosphoric acid. This acid, of the consistence of honey, was put into a retort, and heated nearly to the temperature of boiling water. Alcohol was then introduced by means of a funnel passing to the bottom of the acid, and the mixture distilled. A liquid was obtained, which, when rectified off muriate of lime, yielded an ether possessing all the properties of sulphuric ether.

Besides these ethers, several others have been formed by means of other acids. Indeed, from the late experiments of Thenard, there is reason to believe that almost all the remaining acids may be made to combine with alcohol, and to form a liquid which might be denominated an ether, by distilling a mixture of alcohol, sulphuric acid, and the acid in question.

From the preceding detail, it appears that there are two kinds of ether essentially distinct: The first consisting of sulphuric and phosphoric ethers is formed by the decomposition of alcohol, and contains no acid. All the others contain an acid, and several of them seem to be combinations of an acid and alcohol. Alcohol appears to have the property of neutralizing acids, a property not suspected till lately; though several other vegetable substances seem to possess the same property.

SECT. III. *Volatile Oils.*

The term *oil* is applied to a number of liquids, which, when dropt upon paper, sink into it, and make it semitransparent, or give it what is called a *greasy* stain. Chemists have divided them into two classes, *fixed* and *volatile.*

Volatile oils, called also *essential oils,* are distinguished by the following properties:

1. Liquid, often as liquid as water; sometimes viscid.
2. Very combustible.
3. An acrid taste and a strong fragrant odour.
4. Volatilized at a temperature not higher than 212°.
5. Soluble in alcohol, and imperfectly in water.
6. Evaporate without leaving any stain on paper.

Volatile oils are almost all obtained from vegetables, and they exist in exery part of plants except the colyledons of of the seed, where they have never been found. They are sometimes obtained from plants by simple expression. But in general they are procured by mixing the vegetable substance containing them with water, and distilling. The oil comes over along with the water, and swims on its surface in the receiver.

They are very numerous, but a detailed account of each would not be interesting; a general account of their properties will be sufficient for our purpose.

Most of them are liquid. Some indeed are as liquid as water, as oil of turpentine. Some are viscid, and some of the consistence of butter, or even more solid.

Their colours are very various. Some are colourless like water. Some yellow, brown, blue, green, &c.

Their odours are so various as to defy all description. It is sufficient to say, that all the fragrance of the vegetable kingdom resides in volatile oils. Their taste is acrid, and sometimes they are even corrosive.

Their specific gravity is also various. Oil of turpentine, the lightest oil known, is 0·792, and oil of sassafras, the heaviest, is 1·094.

They evaporate very readily in the open air, diffusing their fragrant odour around. In close vessels the heat necessary to distill them over appears to be greater. When cooled they congeal; but the temperature necessary to produce this effect varies in different oils. Some become solid at 50°, others not till cooled down to —17°. Several of them yield crystals of camphor and of benzoic acid when thus treated.

When exposed to the light, they acquire consistency, and assume a brown colour. Dr Priestley ascertained, that they imbibe oxygen with avidity. Probably these changes are connected with that absorption. By long exposure several of them assume the form of resins.

When heated sufficiently, they take fire, and burn with a strong yellow flame, emitting a great quantity of smoke. The products of the combustion, besides the soot deposited, are water and carbonic acid.

When agitated in water, they render it milky, and communicate their peculiar odour. They dissolve in alcohol, ether and fixed oils.

They dissolve a little phosphorus and sulphur, but do not act on hydrogen or charcoal.

The alkalies and earths act but feebly on the volatile oils. The compounds formed have been called *saponules*. It is probable that they assume the form of resins before they combine with these bodies.

Sulphuric acid decomposes them, converting them first into a kind of resin, and at last into charcoal. Concentrated nitric acid sets them on fire. The diluted acid converts them into a kind of yellow resin.

They scarcely act upon metals; but they have a tendency to reduce some of the metallic oxides.

From the products obtained when the volatile oils are burnt, it has been concluded that they are compounds of carbon and hydrogen. But no exact analysis of any of them has hitherto been made.

SECT. IV. *Of Fixed Oils.*

The fixed oils, which are of so extensive utility, have been known from the remotest ages. They may be distinguished by the following properties.

1. Liquid, or easily become so when exposed to a gentle heat.
2. An unctuous feel.
3. Very combustible.
4. A mild taste.
5. Boiling point not under 600°.

6. Insoluble in water and alcohol.

7. Leave a greasy stain upon paper.

These oils, called also *fat*, or *expressed oils*, are obtained partly from animals, partly from vegetables by simple expression. They occur chiefly in the seeds of bicotyledinous plants, and in the livers of animals. Whale oil, spermaceti oil, olive oil, and linseed oil may be mentioned as examples of fixed oils.

Fixed oil is usually liquid with a certain degree of viscidity. It has usually a yellowish or greenish tinge. Its taste is sweet or nearly insipid. When fresh it has no smell.

Many solid bodies also are obtained from vegetables which have been hitherto confounded with the fixed oils, as palm oil, shea butter, &c. From the late experiments of Dr Bostoch, these substances seem to approach the nature of wax rather more than that of fixed oils.

The fixed oils are all lighter than water. Their specific gravity varies from 0·968 to 0·892.

Fixed oil does not begin to evaporate till heated above 212°. As the heat encreases a pretty copious vapour may be seen to rise. But the oil does not begin to boil till heated nearly to 600°. It may be distilled over, but it is always altered by the process. Some water and acetic acid seem to be formed, heavy inflammable air is given out. The oil deepens in colour and acquires a disagreeable taste and smell.

Fixed oil when kindled burns with a yellowish white flame and is decomposed. The products are carbonic acid and water. When exposed to cold they congeal or crystallize and at the same time their bulk diminishes very considerably.

When exposed to the action of air, they undergo different changes according to the nature of the oil. They gradually absorb oxygen and become solid. Now there are some that retain their *transparency* after they have become solid, while others assume the appearance of *tallow* or *wax*. Those that remain transparent are called *drying oils;* those that become opake, are called *fat oils*.

The drying oils are used as a vehicle of paints and varnishes. Linseed, nut, poppy and hempseed oils belong to this class. They acquire the property of drying oils more completely after they have been boiled. For some purposes it is common to set them on fire, and, after they have burnt for some time, to extinguish them and continue the boiling till they have acquired the requisite viscidity. By this process, they lose the property of leaving a greasy stain upon paper, and acquire many properties in common with the resins. In this way, nut-oil and linseed-oil are prepared for printers ink. The oil, thus altered, still continues insoluble in water and alcohol, but it readily unites with fixed oil.

The *fat oils*, when exposed to the air, gradually become thick, opake and white, and assume an appearance very much resembling wax or tallow. Olive-oil, oil of sweet-almonds, of rape-seed and of ben, may be mentioned as examples of this class.

The action of the simple combustibles on the fixed oils is not very remarkable. Hydrogen has no action. Charcoal renders them purer when they are filtered through it; but separates from them with such difficulty that it cannot be employed for that purpose with advantage.

They dissolve a little phosphorus and sulphur when assisted by heat.

They are insoluble in water, alcohol and ether; but they unite readily with each other, with volatile oils, with bitumens and with resins.

The fixed alkalies combine with them readily, and form with them the important compound called *soap*. Potash forms with them only soft soap, while soda forms hard soap

The earths likewise and metallic oxides combine with the fixed oils, and form a kind of soap insoluble in water.

Sulphuric acid gradually decomposes the fixed oils, blackening their colour, and at last evolving charcoal. Nitric acid acts with still greater energy. When poured suddenly on the drying oils it sets them on fire. When sufficiently diluted, it converts them all into substances similar to resins or tallow.

The fixed oils oxidize some of the metals, as copper and mercury. They combine with various metallic oxides, as those of arsenic, lead and bismuth, and are capable of forming with several the viscid compounds called *plasters*.

They are liable, by keeping, to become *rancid*. They become thick, acquire a brown colour, an acrid taste, and a disagreeable smell. The oil, thus altered, converts vegetable blues to red, and of course contains an acid. This change is, at present, ascribed to a decomposition of the mucilaginous matter which is dissolved in all oils, or to the action of that matter in the oil.

When oils are burnt, the only products are carbonic acid and water. Lavoisier, from a set of experiments made in this way on olive-oil, deduced its composition as follows.

Carbon,	79
Hydrogen,	21
	100

Many oils occur in the vegetable kingdom which are intermediate in their properties between the fixed and volatile oils. Like the volatile oils they are soluble in alcohol; but, like the fixed, they cannot be distilled over with that liquid. Hence they may be obtained by digesting the substance containing them in alcohol, and then separating the alcohol by evaporation.

Many oils are formed when animal and vegetable bodies are exposed to a heat above that of boiling water. These oils are called *empyreumatic*. They are usually dark-coloured, have an acrid taste and a disagreeable smell, and possess most of the properties of the volatile oils.

SECT. V. *Of Bitumens.*

The term *bitumen* has been often applied to all the inflammable substances which occur in the earth. But it is better to limit it to those *fossil bodies* only which have a certain resemblance to oily and resinous substances. They may be divided into two classes. The first set possess nearly the properties of volatile oils; while the second set possess a peculiar character. The first class may be called *bituminous oils*. The second *bitumens proper*.

1. *Bituminous Oils.*

Only two species of bituminous oils have been hitherto examined, namely *naphtha* and *petroleum*, and *maltha* or *sea-wax*.

1. Naphtha, or petroleum, is an oil of a brownish yellow colour. When pure, fluid as water and pretty volatile. Its specific gravity varies from 0·730 to 0·878. It has a peculiar smell. When heated it may be distilled over without alteration. It unites with alcohol, ether, volatile and fixed oils, and, as far as is known, possesses all the characters of volatile oils.

When found in the earth pure, it is distinguished by the name of *naphtha*; when less fluid and darker coloured, it is called *petroleum*. When petroleum is distilled, naphtha is obtained from it.

2. Maltha, or sea-wax, is a solid substance found on the Baikal lake in Siberia. It is white, melts when heated, and on cooling assumes the consistence of white cerate. It dis-

solves in alcohol, and seems to possess the character of a solid volatile oil.

2. *Proper Bitumens.*

The true bituminous substances may be distinguished by the following properties:

1. They are either solid or of the consistence of tar.

2. Their colour is usually brown or black.

3. They have a peculiar smell, or at least acquire it when rubbed. This smell is known by the name of the *bituminous odour*.

4. They become electric by friction, though not insulated.

5. They melt when heated, and burn with a strong smell, a bright flame, and much smoke.

6. They are insoluble in water and alcohol, but dissolve most commonly in ether and in fixed and volatile oils.

7. They do not dissolve in alkaline leys nor form soap.

8. Acids have little action on them; the sulphuric scarcely any: the nitric by long and repeated digestion, dissolves them and converts them into a yellow coloured substance, soluble both in water and alcohol.

The pure bitumens at present known are three, namely, *asphaltum*, *mineral tar*, and *mineral caoutchouc*. United to resin it forms a curious substance called *retinasphaltum*. United to charcoal it forms the various species of pit-coal so important as articles of fuel.

1. Asphaltum. This substance occurs in great abundance in the island of Trinidad, on the shores of the dead sea, in Albania and in other places. Its colour is black with a shade of brown, red, or grey. It is heavier than water. It is insoluble in acids, alkalies, water and alcohol; but soluble in oils, petroleum and sulphuric ether.

2. Mineral tar. This substance is found in Barbadoes and other places. It is named from its consistence and appearance. It seems to be a mixture of petroleum and asphaltum. Accordingly when distilled, abundance of petroleum is obtained, of a brown colour, but very fluid.

3. Mineral caoutchouc is a singular substance, hitherto found only in Derbyshire. It is soft and elastic, not unlike common caoutchouc or Indian rubber. Its colour is dark-brown, with a shade of green or red. It resists the action of almost all liquid menstrua. Neither alcohol, alkalies nor nitric acid affect it. Even oils and petroleum are incapable of dissolving it. When heated, it melts and continues afterwards of the consistence of tar. In that state it is soluble in oils. It burns with a bright flame and bituminous smell.

4. Retinasphaltum has hitherto been found only in Derbyshire accompanying Bovey coal. Mr Hatchett discovered its nature. It has a pale brown ochre yellow colour, is very brittle, and breaks with a vitreous fracture. Its specific gravity is 1·135. When heated it melts, smokes and burns with a bright flame, and emits a fragrant odour. It is insoluble in water, but partially soluble in alcohol, potash and nitric acid. It is composed of

Resin,	55
Asphaltum,	41
Earths,	3
	99

5. Pit-coal, one of the most useful of all the mineral productions, may be distinguished into three kinds. 1. Those that still contain vegetable principles, strictly so called, and thus give evident marks of their origin. Some yield *extractive*, others *resin*, besides charcoal and bitumen, which constitute the greatest part of their contents. The term *brown coal*, from their colour, has been applied to the greater num-

ber of coals belonging to this set. 2. *Black coal.* In them no vegetable principle can be detected, they are composed of bitumen and charcoal in various proportions, and are usually mixed with more or less of earthy matter. 3. *Glance coal.* In this set no vegetable principle nor even bitumen is to be found. The coal consists of charcoal pure, or contaminated with some earth. These coals have a great deal of lustre. They are heavy, and burn without emitting any flame or smoke, and only when heated to redness.

DIVISION III.

OF SECONDARY COMPOUNDS.

By the term *secondary compound*, is meant a combination of *salifiable bases*, or *primary compounds* with each other. Thus acids combine with alkalies and form *salts*, earths combine with fixed alkalies and form *glass*, oils combine with fixed alkalies and form *soap*. The secondary compounds, as far as we are at present acquainted with them, may be arranged under the five following classes.

1. Combinations of earths with each other and with metallic oxides.

2. Combinations of earths with alkalies.

3. Combinations of acids with alkalies, earths and metallic oxides.

4. Combinations of sulphureted hydrogen with alkalies, earths and metallic oxides.

5. Combinations of oils with alkalies, earths and metallic oxides.

These combinations may be distinguished by the following titles. 1. Combinations of earths; 2. Glass; 3. Salts; 4. Hydrosulphurets; 5. Soaps.

CHAP. I.

OF COMBINATIONS OF EARTHS.

This subject is in some measure new and has been but imperfectly investigated. The following observations are all that can be offered:—

1. The earths require so violent a heat to melt them that they are capable of resisting the most intense fires that we can raise. But in several cases the fusion is much facilitated by mixing various earths together. Thus alumina in a pure state is infusible, and so is a mixture of alumina and silica or *pure clay*. But when lime is added to this substance it melts with comparative facility. The oxide of iron also acts as a solvent when mixed with other earthy bodies, and greatly facilitates their fusion.

2. The three alkaline earths, lime, barytes and strontian resemble each other in their disposition to unite with the other earths. Like the alkalies they combine with alumina and silica, but shew no affinity for magnesia nor for each other.

3. Magnesia has a marked affinity for alumina but for none of the other earths. When magnesia and alumina are present together in solutions, alkalies throw them down in combination.

4. Alumina has an affinity for all the alkaline earths. It has also an affinity for silver. These two earths are frequently found combined in nature.

5. Silver has an affinity for the alkaline earths, for alumina and for zirconia. Silver enters into fusion with all the earths hitherto tried except alumina.

6. Several of the earths are capable of combining likewise with metallic oxides. Hitherto only six metals in the state of oxides have been found native combined with earths. These are, 1. chromium; 2. nickel; 3. copper; 4. zinc; 5. manganese; 6. iron.

Chromium constitutes the colouring matter of the *ruby*, in which mineral it is combined with alumina and magnesia. Nickel has been found only in one mineral the *chrysoprase*, to which it gives a green colour. The same remark applies to copper which has been found only in the *smaragdite* and in a very small proportion. Zinc is sometimes found combined with silica in the mineral called *calamine*, which is frequently merely an oxide of zinc. The oxide of manganese is a very frequent ingredient in dark coloured stones, as *schorl*, *garnet*, &c. It is found also combined with barytes.

But it is the oxide of iron which constitutes by far the most common metallic constituent of minerals. No less than seven distinct colours besides various shades have been observed in minerals containing iron. These are *white*, *black*, *green*, *blue*, *red*, *yellow*, *brown*.

The oxides of iron melt when heated with barytes, lime, alumina or silica when they exceed the proportion of earth considerably. They render mixtures of silica and alumina fusible at a very low heat.

CHAP. II.

OF GLASS.

Silica when mixed with the fixed alkalies and exposed to a strong heat enters readily into fusion. It melts also when heated along with some of the alkaline earths, as lime, provided a little alumina be present. These mixtures are very ductile while in fusion and may be readily moulded into any shape we please. If they be suddenly cooled below the temperature at which they become solid, they retain their transparency, and assume those peculiar properties which belong to the substance called *glass*. *Glass*, then, is a combination of the fixed alkalies or alkaline earths with silica, either alone or conjoined with alumina, brought into complete fusion, and then suddenly congealed. Metallic oxides are sometimes added; they assist the fusion like the alkalies, and communicate frequently a peculiar colour to the vitreous mass.

When glass is in fusion, the substances which enter into its composition may be considered as combined with each other, so as to form a homogeneous mass similar to water holding a variety of salts in solution. If it be cooled down very slowly, the different tendency of the constituents to assume a solid form at peculiar temperatures will cause them to separate successively in crystals; just as the salts held in solution in water, assume the form of crystals as the liquid is slowly evaporated. But if the glass be quickly cooled down to the point of congelation, the constituents have not time to separate in succession, and the glass remains the same homogeneous compound as while in a state of fusion; just as would happen to a saline solution if suddenly exposed to a cold capable of congealing it completely. Hence, it appears, that the vitreous quality depends entirely upon the fusibility of the mixture, and the suddenness with which it is cooled down to the point of congelation. The substance, though solid, is precisely the same as to its chemical composition, as if it were still in fusion; the sudden cooling having fixed the constituents before they had time to assume a new arrangement.

All fusible mixtures of the earths proper with fixed alkalies, alkaline earths or metallic oxides may be made at pleasure to assume the form of glass, or the appearance which characterises stone or porcelain, according to the rate of cooling; and glass may be deprived of its vitreous form merely by fusing it and cooling it down with sufficient slowness to enable the constituents to separate in succession. Sir James Hall found that glass (consisting of various earthy bodies) always loses its vitreous state and assumes that of a stone, if more than a minute or two elapses while it is cooling down from complete fusion to the point at which it congeals.

There are different kinds of glass in common use for various purposes. The finest are *plate glass* and *flint glass* or *crystal*. They are perfectly transparent, nearly colourless, heavy and brilliant. They are composed of fixed alkali, pure siliceous sand or calcined flints, and litharge. *Crown glass* is made without lead; it consists of fixed alkali and siliceous sand, and is much lighter than flint glass. It has a distinct greenish tinge from the oxide of iron present in the materials employed in making it. Sometimes too great a proportion of oxide of manganese is added, which gives it a purple colour. *Bottle glass* is the coarsest and cheapest kind. It consists chiefly of lime fused with silica and a little alumina and contains so much iron and manganese as to give it a dark colour and to diminish its transparency very much. It is much harder, stronger, and more difficultly fusible than the fine kinds of glass.

Glass answers well as a chemical vessel, as it is acted on only by a small number of re-agents. Fluoric acid corrodes it readily, so do the fixed alkalies when assisted by heat. Water when long boiled in it disengages some alkali from it, and occasions the separation of silica in the state of a white powder.

CHAP. III.

OF SALTS.

The world *salt* was originally confined to *muriate of soda* or *common salt*, a substance which has been known and in common use from the remotest ages. The term was afterwards generalized by chemists and applied to all bodies which are sapid, easily melted, soluble in water and not combustible. At length it was confined to acids, alkalies, and the combinations of these bodies with each other. At present the term is applied to all the compounds which the acids form with alkalies, earths and metallic oxides.

Chemists have agreed to denominate the salts from the *acids* which they contain. The alkali, earth or metallic oxide, combined with that acid is called the *base* of the salt. Thus common salt, being a compound of muriatic acid and soda, is called a *muriate* and soda is called the *base* of common salt. Hence it follows that there are as many genera of salts as there are acids, and as many individual salts or species as there are combinations of acids with a base. Silica and some of the metallic oxides do not appear capable of combining with acids. But to compensate this there are some acids which combine with two bases at once, and form what are called *triple salts*. Thus *tartaric acid* combines at once with *potash* and *soda*. Some salts combine with an additional dose of their acid, and others with an additional dose of their base. The first render vegetables blue, the second usually render them green. The first kind of salts are distinguished by prefixing to the usual name the preposition *super*, the second by prefixing the preposition *sub*. Thus *sulphate of potash*, denotes the salt in a state of perfect neutralization without any excess either of acid or potash; *supersulphate of potash* is the same salt with an excess of acid; *subsulphate* of potash is the same salt with an excess of base.

As the different genera are denominated from the acids, it is obvious that there must be as many genera as there are acids. The termination of the names of these genera differs according to the acid which constitutes them. When the acid contains a maximum of oxygen, the termination of the genus is *ate,* when it does not contain a maximum of oxygen the termination of the genus is *ite.* Thus the salts which contain *sulphuric acid* are called *sulphates;* those which contain *sulphurous acid* are called *sulphites.* This distinction is of some consequence, because the salts differ very much according as the acid is saturated with oxygen or not. The *ites* are seldom permanent; when exposed to the air they usually attract oxygen and are converted into *ates.*

Every particular species of salt is distinguished by subjoining to the generic term the name of its base. Thus the salt composed of sulphuric acid and soda, is called *sulphate of soda.* Triple salts are distinguished by subjoining the names of both the bases connected by hyphens. Thus the salt composed of tartaric acid, potash and soda is called *tartrate of potash-and-soda.* Sometimes instead of this, one of the bases is prefixed to the name by way of adjective. Thus *soda-muriate of rhodium* means the triple salt composed of muriatic acid, soda and the oxide of rhodium. Sometimes the name of the base prefixed is altered a little; as, *ammonio-sulphate of magnesia (sulphate of magnesia-and-ammonia); ferruginous sulphate of zinc (sulphate of zinc-and-iron.)*

The salts naturally divide themselves into two classes. Those which contain an alkali or earth for their base, derive their chief properties from the acids, and are properly enough characterised by the name of the acids applied to the names of the genera. But those which have for their base a metallic oxide, derive their characteristic properties from that base, and ought therefore to be arranged according to it. We shall therefore divide this chapter into two sections, in the first we shall treat of the salts with alkaline and earthy bases; in the second, of the salts with metallic bases:

SECT. I. *Of Alkaline and Earthy Salts.*

As the genera of these salts (derived from their acids) are very numerous, it will be advantageous to the learner if we subdivide them into sets according to their properties: this is attempted in the following table:—

I. Incombustible Salts.
  a. Not altered when heated with charcoal.
    1. Muriates.
    2. Fluates.
    3. Borates.
    4. Phosphates *.
  b. Decomposed without combustion when heated with charcoal.
    1. Sulphates.
    2. Carbonates.
  c. Set fire to charcoal or yield oxygen gas by heat.
    1. Nitrates.
    2. Nitrites.
    3. Hyper-oxymuriates.
    4. Arseniates.
    5. *Molybdates.*

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[*] The phosphates are decomposed when violently heated with charcoal, but the temperature required is so high that the decomposition cannot be effected in ordinary fires. Except the phosphate of ammonia which is decomposed pretty easily.

6. *Tungstates.*
7. *Chromates.*
8. *Columbates**.

II. Combustible Salts.

a. Acids partially dissipated by heat, leaving salts in *ate*.

1. Sulphites.
2. Phosphites.

b. Acids entirely dissipated by heat, leaving the base and charcoal.

+ Acids partly sublimed unaltered.

1. Acetates.
2. Succinates.
3. Moroxylates.
4. Benzoates.
5. Camphorates.

+ + Acids wholly decomposed.

6. Oxalates.
7. Mellates.
8. Tartrates.
9. Citrates.
10. Kinates.
11. Saccolates.
12. Urates.
13. Sebates.
14. Malates.
15. Formiates.
16. Suberates.

+ + + Anomalous.

17. Gallates.

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* The nitrate and hyperoxymuriate of ammonia are combustible alone. They are completely dissipated when heated. The genera in italics are placed from analogy only.

18. Prussiates.

Let us take a view of these genera in their order.

GENUS I. *Muriates.*

The muriates are all soluble in water, and several of them likewise in alcohol. When mixed with sulphuric acid they effervesce, and white acrid fumes with the odour of muriatic acid are exhaled. They are in number 12.

Sp. 1. *Muriate of Potash.* This salt crystallizes in irregular cubes. Its taste is salt and rather bitter. It dissolves in thrice its weight of cold water. Little altered by exposure to the air. In a red heat it melts and loses about three per cent. of its weight. Not sensibly soluble in alcohol.

Sp. 2. *Muriate of Soda* or *Common Salt.* This salt has been in common use as a seasoner of food from the earliest ages. It exists abundantly in sea water from which it is obtained by evaporation. Mines of it occur also in different parts of the world. It crystallizes in cubes. Its taste is universally known, and is what strictly speaking is denominated salt. It dissolves in rather less than thrice its weight of water, and is nearly equally soluble in cold and hot water. It is insoluble in pure alcohol. It deliquesces somewhat when exposed to moist air. In a red heat it melts and loses about two per cent. of its weight. In a violent heat it evaporates.

Sp. 3. *Muriate of Ammonia.* This salt was named *sal ammoniac* because it was found native near the temple of Jupiter Ammon in Africa. It is usually in the form of hard elastic cakes. But by solution and evaporation it may be obtained crystallized in long four-sided pyramids. It deliquesces a little when exposed to moist air. It is soluble in about thrice its weight of water, and in about 75 parts of alcohol. When heated, it sublimes without decomposition in a white smoke.

Sp. 4. *Muriate of Magnesia.* This salt exists in sea-water. It is not easily crystallized, but when its solution, properly concentrated, is exposed to a sudden cold, it may be obtained in small needles. Its taste is very bitter, hot and biting, It dissolves in about half its weight of water; and in about twice its weight of pure alcohol. When exposed to the air it speedily deliquesces. A strong heat decomposes it. When dried in a high temperature, it is very caustic.

Sp. 5. *Muriate of Ammonia-and-Magnesia.* This salt is obtained when the solutions of the two last salts are mixed together. Its crystals are small and irregular, its taste bitter and ammoniacal. It dissolves in about six times its weight of cold water.

Sp. 6. *Muriate of Lime.* This salt is not easily procured in crystals on account of its great solubility in water. Its crystals are six-sided striated prisms, terminated by very sharp pyramids. Its taste is very bitter and pungent. At the temperature of 60°, water dissolves four times its weight of this salt, and it dissolves any quantity whatever, at the temperature of 100°. Alcohol seems capable of dissolving more than its own weight of this salt. This salt deliquesces very speedily when exposed to the atmosphere. When heated it melts and loses its water of crystallization. In a violent heat it loses also a portion of its acid, and then has the property of shining in the dark. In that state it is called the *phosphorus of Homberg.*

Sp. 7. *Muriate of Barytes.* This salt crystallizes in four-sided prisms, whose bases are squares; but it is obtained more commonly in tables. It has a pungent and disagreeable taste, and like all other preparations of barytes is poisonous. It requires rather more than twice its weight of water to dissolve it. It is not sensibly soluble in pure alcohol. It is not altered by exposure to the air. In a red heat it melts but is not decomposed.

Sp. 8. *Muriate of Strontian.* This salt crystallizes in long slender hexagonal prisms, usually so minute as to have the appearance of needles. It dissolves in rather less than its weight of cold water, while boiling water dissolves any quantity of it whatever. It dissolves in about 24 parts of pure alcohol. The crystals are not much altered by exposure to the air. When heated they undergo the watery fusion, and in a red heat are converted to a white powder.

Sp. 9. *Muriate of Alumina.* This salt is always in the state of a supermuriate. It hardly crystallizes, being always either gelatinous or in the state of a white mass. Water dissolves about four times its weight of it. It speedily deliquesces in the air. Alcohol dissolves at least half its weight of this salt. When heated it melts and loses its acid.

Sp. 10. *Muriate of Yttria.* This salt does not crystallize, but runs to a jelly. It melts in a gentle heat, and attracts moisture very rapidly from the atmosphere.

Sp. 11. *Muriate of Glucina.* This salt has a sweet taste and readily crystallizes.

Sp. 12. *Muriate of Zirconia.* This salt is transparent and crystallizes in needles which effloresce in the air. It is very soluble in water and in alcohol. Heat decomposes it with facility.

The following table exhibits the composition of these salts according to the most accurate experiments hitherto made

Muriates of	*Constituents.*		
	Acid.	*Base.*	*Water*
Ammonia	100	58·4	75·4
Magnesia	100	89·8	99·3
Soda	100	114	14
Lime	100	118·3	
Potash	100	185·7	
Strontian	100	216·2	233
Barytes	100	314·5	87
Alumina	100	100	135

The three last species have not hitherto been analysed.

GENUS II. *Fluates.*

Most of these salts are but sparingly soluble in water, and hitherto they have been but superficially examined. When sulphuric acid is poured on them, they exhale acrid fumes, which readily act upon glass and corrode it.

Sp. 1. *Fluate of Potash.* This salt is hardly known. It is said to crystallize when pure. It has but little taste, dissolves readily in water, and melts when heated. It combines readily with silica, and forms a white powder, loose like chalk, containing an excess of acid.

Sp. 2. *Fluate of Soda.* This salt crystallizes in cubes. Its taste is bitter and astringent. It is sparingly soluble in water. When heated it decrepitates and melts into a transparent globule.

Sp. 3. *Fluate of Ammonia.* This salt crystallizes and may be sublimed without decomposition.

Sp. 4. *Fluate of Alumina.* This salt does not crystallize, but is easily obtained in the state of a jelly. Its taste is astringent, and it always contains an excess of acid.

The remaining fluates are insoluble in water.

Sp. 5. *Fluate of Magnesia.* When this salt contains an excess of acid, it may be obtained in dodecahedrons. Heat does not decompose this salt.

Sp. 6. *Fluate of Lime.* This salt occurs native in abundance, and is the only fluate that has been accurately examined. It is usally crystallized in cubes, sometimes in octahedrons. It has no taste, nor is it altered by exposure to the air. Its specific gravity is 3·15. When heated, it decrepitates and phosphoresces strongly. When strongly heated it melts into a transparent glass. According to my analysis, it is composed of 32⅔ acid and 67⅓ lime.

Sp. 7. *Fluate of Barytes.* This is a white tasteless powder not hitherto examined.

Sp. 8. *Fluate of Alumina-and-Soda.* This salt has been found in Greenland, and is called *cryolite* by mineralogists. Its colour is greyish white. It has some transparency. It breaks into cubic fragments. Its specific gravity is 2·950. It is brittle and softer than fluate of lime. It is composed of

Acid and water,	40
Soda, - - -	36
Alumina, - -	24
	100

Sp. 9. *Fluate of Silica.* Fluoric acid, as usually obtained, contains, in solution, a quantity of silica. When kept in vessels not completely shut, it deposites small rhomboidal crystals of silica.

GENUS III. *Borates.*

This genus has been very imperfectly examined. All the fluates, before the blowpipe, melt into a glass. When boiled in diluted sulphuric acid, they yield small scales of boracic acid.

Sp. 1. *Borate of Potash.* This salt crystallizes in four-sided prisms. It has been very little examined.

Sp. 2. *Borate of Soda.* This salt may be formed by saturating borax with boracic acid. It is soluble in 2½ times its weight of hot water.

Sp. 3. *Borax* or *Sub-borate of Soda.* This salt is the only one of the borates which has been accurately examined. It is brought from the East Indies, and has been in common use in Europe for ages. It seems even to have been known to the ancients. It crystallizes in hexangular prisms, but is usually in roundish semi-transparent lumps. Colour white. Specific gravity 1·740. Taste styptic and alkaline. Converts vegetable blues to green. Soluble in about 20 times its weight of cold water, but more soluble in hot water. When exposed to the air it effloresces slowly and slightly. When heated it melts, loses its water of crystallization, and is converted into a light porous substance called *calcined borax.* In a strong heat it melts into a transparent glass, still soluble in water. It is said to be composed of

Acid,	39
Base,	17
Water,	44
	100

Sp. 4. *Borate of Ammonia.* This salt forms permanent crystals, which resemble those of borax. Heat decomposes it.

18. Prussiates.

Let us take a view of these genera in their order.

GENUS I. *Muriates.*

The muriates are all soluble in water, and several of them likewise in alcohol. When mixed with sulphuric acid they effervesce, and white acrid fumes with the odour of muriatic acid are exhaled. They are in number 12.

Sp. 1. *Muriate of Potash.* This salt crystallizes in irregular cubes. Its taste is salt and rather bitter. It dissolves in thrice its weight of cold water. Little altered by exposure to the air. In a red heat it melts and loses about three per cent. of its weight. Not sensibly soluble in alcohol.

Sp. 2. *Muriate of Soda* or *Common Salt.* This salt has been in common use as a seasoner of food from the earliest ages. It exists abundantly in sea water from which it is obtained by evaporation. Mines of it occur also in different parts of the world. It crystallizes in cubes. Its taste is universally known, and is what strictly speaking is denominated salt. It dissolves in rather less than thrice its weight of water, and is nearly equally soluble in cold and hot water. It is insoluble in pure alcohol. It deliquesces somewhat when exposed to moist air. In a red heat it melts and loses about two per cent. of its weight. In a violent heat it evaporates.

Sp. 3. *Muriate of Ammonia.* This salt was named *sal ammoniac* because it was found native near the temple of Jupiter Ammon in Africa. It is usually in the form of hard elastic cakes. But by solution and evaporation it may be obtained crystallized in long four-sided pyramids. It deliquesces a little when exposed to moist air. It is soluble in about thrice its weight of water, and in about 75 parts of alcohol. When heated, it sublimes without decomposition in a white smoke.

Sp. 4. *Muriate of Magnesia.* This salt exists in sea-water. It is not easily crystallized, but when its solution, properly concentrated, is exposed to a sudden cold, it may be obtained in small needles. Its taste is very bitter, hot and biting. It dissolves in about half its weight of water; and in about twice its weight of pure alcohol. When exposed to the air it speedily deliquesces. A strong heat decomposes it. When dried in a high temperature, it is very caustic.

Sp. 5. *Muriate of Ammonia-and-Magnesia.* This salt is obtained when the solutions of the two last salts are mixed together. Its crystals are small and irregular, its taste bitter and ammoniacal. It dissolves in about six times its weight of cold water.

Sp. 6. *Muriate of Lime.* This salt is not easily procured in crystals on account of its great solubility in water. Its crystals are six-sided striated prisms, terminated by very sharp pyramids. Its taste is very bitter and pungent. At the temperature of 60°, water dissolves four times its weight of this salt, and it dissolves any quantity whatever, at the temperature of 100°. Alcohol seems capable of dissolving more than its own weight of this salt. This salt deliquesces very speedily when exposed to the atmosphere. When heated it melts and loses its water of crystallization. In a violent heat it loses also a portion of its acid, and then has the property of shining in the dark. In that state it is called the *phosphorus of Homberg.*

Sp. 7. *Muriate of Barytes.* This salt crystallizes in four-sided prisms, whose bases are squares; but it is obtained more commonly in tables. It has a pungent and disagreeable taste, and like all other preparations of barytes is poisonous. It requires rather more than twice its weight of water to dissolve it. It is not sensibly soluble in pure alcohol. It is not altered by exposure to the air. In a red heat it melts but is not decomposed.

Sp. 8. *Muriate of Strontian.* This salt crystallizes in long slender hexagonal prisms, usually so minute as to have the appearance of needles. It dissolves in rather less than its weight of cold water, while boiling water dissolves any quantity of it whatever. It dissolves in about 24 parts of pure alcohol. The crystals are not much altered by exposure to the air. When heated they undergo the watery fusion, and in a red heat are converted to a white powder.

Sp. 9. *Muriate of Alumina.* This salt is always in the state of a supermuriate. It hardly crystallizes, being always either gelatinous or in the state of a white mass. Water dissolves about four times its weight of it. It speedily deliquesces in the air. Alcohol dissolves at least half its weight of this salt. When heated it melts and loses its acid.

Sp. 10. *Muriate of Yttria.* This salt does not crystallize, but runs to a jelly. It melts in a gentle heat, and attracts moisture very rapidly from the atmosphere.

Sp. 11. *Muriate of Glucina.* This salt has a sweet taste and readily crystallizes.

Sp. 12. *Muriate of Zirconia.* This salt is transparent and crystallizes in needles which effloresce in the air. It is very soluble in water and in alcohol. Heat decomposes it with facility.

The following table exhibits the composition of these salts according to the most accurate experiments hitherto made

The following table exhibits the constituents of the phosphates, according to the experiments of Richter.

Phosphate of	*Acid.*	*Base.*
Alumina	100	53·6
Magnesia	100	62·8
Ammonia	100	68·6
Lime	100	81
Soda	100	87·7
Strontian	100	135·7
Potash	100	164
Barytes	100	222

GENUS V. *Phosphites.*

The salts belonging to this genus have been but little examined by Chemists. When heated, they emit a phosphorescent flame. When strongly heated, they yield a little phosphorus, and are converted into *phosphates.*

Sp. 1. *Phosphite of Potash.* This salt crystallizes in four-sided prisms. Its taste is sharp and saline. It is soluble in 3 parts of cold water. It is not altered by exposure to the air.

Sp. 2. *Phosphite of Soda.* It crystallizes in rhomboids. Its taste is cooling and agreeable. It dissolves in two parts of cold water. It effloresces in the air. Before the blowpipe, it gives out a fine yellow flame, and melts into a globule which becomes opake in cooling.

Sp. 3. *Phosphite of Ammonia.* It crystallizes in four-sided prisms. Its taste is sharp and saline. It dissolves in two parts of cold water. It deliquesces a little. When heated, it loses its base; emits phosphureted hydrogen gas, and phosphoric acid remains.

Sp. 4. *Phosphite of Ammonia-and-Magnesia.* This salt is sparingly soluble in water, and crystallizes.

Sp. 5. *Phosphite of Alumina.* This salt does not crystallize, but forms a glutinous mass which dries gradually, and does not afterwards attract moisture. It is very soluble in water. Its taste is astringent.

The remaining phosphites are insoluble in water.

Sp. 6. *Phosphite of Magnesia.* This salt is usually in the state of a white powder, or of small four-sided prisms. It effloresces in the air. It is said to be soluble in 400 parts of cold water.

Sp. 7. *Phosphite of Lime.* This is a white tasteless powder, insoluble in water, but soluble in phosphorous acid, forming a superphosphite, which may be obtained in prismatic crystals by evaporation.

Sp. 8. *Phosphite of Barytes.* This is a white powder, hardly soluble in water, unless there be an excess of acid.

GENUS VI. *Carbonates.*

This is one of the most important of the saline genera. When muriatic or nitric acid is poured on them, they effervesce, and give out carbonic acid. When fully saturated they do not affect vegetable blues, but the alkaline *subcarbonates* convert vegetable blues to green.

Sp. 1. *Carbonate of Potash.* Of this salt there are two varieties, the *carbonate* and *subcarbonate.*

Variety 1. *Carbonate.* This salt may be formed by causing a current of carbonic acid to pass through a solution of potash, till the salt crystallizes. It crystallizes in rhomboidal prisms, with dihedral summits. It has a very slight alkaline taste, and still gives a green colour to vegetable blues. It is soluble in four parts of cold water. Alcohol scarcely dissolves it. Exposure to air does not alter it.

Variety 2. *Subcarbonate.* This salt is obtained by exposing the preceding to a strong red heat. It contains exactly one half of the acid contained in the carbonate. It is much more soluble in water; its taste is very alkaline and caustic; and when exposed to the air, it soon deliquesces and runs into a liquid. The potash of commerce is always in the state of a subcarbonate.

Sp. 2. *Carbonate of Soda.* Of this salt, like the preceding, there are two varieties.

Variety 1. *Carbonate.* This salt occurs native in Africa, and may be formed by passing a current of carbonic acid through a solution of soda, till it ceases to absorb any more. It runs into a hard solid mass, which is not altered by exposure to the air.

Variety 2. *Subcarbonate.* What is called carbonate of soda in commerce, is nothing else than this salt. Its crystals are octahedrons, having their apexes truncated, or more commonly flat rhomboidal prisms. It dissolves in two parts of cold water. When exposed to the air, it effloresces and falls to powder. When heated, it undergoes the watery fusion, and melts in a red heat into a transparent liquid.

Sp. 3. *Carbonate of Ammonia.* Of this salt, also, there are at least two varieties.

Variety 1. *Carbonate.* This salt may be obtained by passing a current of carbonic acid through the subcarbonate dissolved in water. It crystallizes in six-sided prisms; has no smell, and much less taste than the subcarbonate. When heated it sublimes, and is decomposed.

Variety 2. *Subcarbonate.* This salt crystallizes, but the crystals are small and irregular. Its smell and taste are similar to those of ammonia, though weaker. It is lighter than water. It is soluble in less than twice its weight of water. From the experiments of Davy, it would appear that there are different varieties of this salt, containing various proportions of acid, according to the temperatures in which it has been prepared.

Sp. 3. *Carbonate of Ammonia-and-Magnesia.* This salt may be formed by mixing together aqueous solutions of its two constituents. Its properties have not been examined.

The remaining carbonates are insoluble in water.

Sp. 5. *Carbonate of Magnesia.* Of this salt, there are likewise two varieties.

Variety 1. *Subcarbonate.* This is a light white powder, constituting the magnesia of commerce.

Variety 2. *Carbonate.* It may be formed by diffusing the preceding variety in water, and passing a current of carbonic acid through the liquid. It crystallizes in six-sided transparent prisms. It has little taste. It dissolves, when in crystals, in 48 parts of cold water. It effloresces in the air, and falls to powder.

Sp. 6. *Carbonate of Lime.* This salt, under the names of marble, chalk, limestone, calcareous spar, &c. exists in great abundance in nature. It crystallizes in rhomboidal prisms, with angles of 101½° and 78½°; and no less than 616 different varieties of form have been observed and described by mineralogists. It is tasteless, insoluble in water, but soluble in a small proportion by means of carbonic acid. When heated strongly, its loses its acid, and the escape of the acid is greatly facilitated by the presence of vapour. When suddenly heated, it melts without losing its acid, and assumes a form bearing some resemblance to granular limestone.

Sp. 7. *Carbonate of Barytes.* This salt is found native, and distinguished by mineralogists by the name of Witherite. It crystallizes in double six-sided and four-sided pyramids. It is tasteless, insoluble in water, but poisonous. It is not altered by exposure to the air. When made up into a ball with charcoal, and violently heated, it loses its acid.

Sp. 8. *Carbonate of Strontian.* This salt also occurs native, usually in semi-transparent striated masses, with a greenish tinge. It is tasteless, insoluble in water, and not altered by exposure to the air. When violently heated it loses its acid.

Sp. 9. *Carbonate of Alumina.* Water, containing carbonic acid gas, dissolves a little alumina; but when the alumina is precipitated and dried, it appears, from the experiments of Saussure, that it loses its acid. Carbonate of alumina, then, cannot exist in a dry state.

Sp. 10. *Carbonate of Yttria.* A white, tasteless, insoluble powder.

Sp. 11. *Carbonate of Glucina.* A white, soft, tasteless powder, with greasy feel.

Sp. 12. *Carbonate of Zirconia.* A white tasteless powder.

The following table exhibits a view of the composition of these salts as far as it has been ascertained.

Carbonate of	*Acid.*	*Base.*	*Water.*
Ammonia	100	33·9	44·6
Magnesia	100	50	50
Potash	100	95·3	37
Soda	100	97·4	59
Lime	100	122	
Strontian	100	231	
Yttria	100	305·5	150
Barytes	100	354·5	

The subcarbonates appear to contain just one half of the acid which exists in the carbonates.

GENUS VII. *Sulphates.*

This genus of salts has been long known, and very carefully examined. Most of the salts in it crystallize. Their taste is usually bitter. They are insoluble in alcohol, and precipitated from water by alcohol. When heated to redness, along with charcoal, they are converted into sulphurets. All their solutions yield a white precipitate, insoluble in cold sulphuric acid, when mixed with muriatic of barytes.

Sp. 1. *Sulphate of Potash.* Of this salt there are two varieties.

Variety 1. *Sulphate.* This salt is usually to be found in considerable quantity in the potash of commerce. The crystals are small, irregular, hard, and firm: usually six-sided prisms. The taste is a disagreeable bitter. It dissolves in about 16 times its weight of cold water. It is not altered by exposure to the air. In a red heat it melts, and loses about 1½ per cent. of its weight.

Variety 2. *Supersulphate.* This salt may be obtained by dissolving the preceding in sulphuric acid, and evaporating. Its crystals are long, slender needles, or six-sided prisms. Its taste is acid, and it reddens vegetable blues. When heated it melts, and assumes the appearance of oil. A strong red heat is necessary to drive off the excess of acid, and convert it into *sulphate.*

Sp. 2. *Sulphate of Soda.* This salt is often called Glauber's salt, from the name of the discoverer of it. There are two varieties of it, like the preceding.

Variety 1. *Sulphate.* This salt crystallizes in six-sided transparent prisms, terminated by dihedral summits. The sides of the prisms are usually channeled. Its taste, at first, has some resemblance to that of common salt, but it soon becomes disagreeably bitter. It dissolves in less than thrice its weight of cold water, and in less than its weight of boiling water. When exposed to the air, it loses its water, effloresces, and falls to powder. The loss of weight is about 0·56 parts. When heated, it undergoes the watery fusion. In a red heat it melts, and, according to Kirwan, loses part of its acid.

Variety 2. *Supersulphate.* This salt may be obtained by dissolving the preceding variety in sulphuric acid, and evaporating the solution. It crystallizes in large transparent rhombs, which effloresce in the air, and easily part with their excess of acid.

Sp. 3. *Sulphate of Ammonia.* This salt crystallizes in small six-sided prisms. It has a sharp bitter taste; is soluble in twice its weight if cold water, and in its weight of boiling water. When exposed to the air, it slowly attracts moisture. When heated it decrepitates, then melts and sublimes with some loss of its alkali. When heated nearly to redness, the greatest part of it is decomposed.

Sp. 4. *Sulphate of Magnesia.* This salt was long known by the name of *Epsom salt,* because it exists in the spring at Epsom near London. It exists also in sea water. It crystallizes in regular four sided prisms, surmounted by four sided pyramids or dehedral summits. The crystals refract doubly. Its taste is intensely bitter. It dissolves in its own weight of cold water. In the air it effloresces. When heated it undergoes the watery fusion, and before the blow-pipe melts with difficulty into an opake vitreous globule.

Sp. 5. *Sulphate of Potash-and-Ammonia.* This salt crystallizes in brilliant plates. Its taste is bitter, and it is not altered by exposure to the air.

Sp. 6. *Sulphate of Potash-and-Magnesia.* This salt crystallizes in rhomboidal prisms, and is not altered by exposure to the air.

Sulphate of soda is also capable of forming triple salts with ammonia and magnesia.

Sp. 7. *Sulphate of Magnesia-and-Ammonia.* This salt crystallizes in octahedrons. Its taste is acrid and bitter. It is decomposed by heat, and is less soluble in water than either of its constituents.

Sp. 8. *Sulphate of Alumina.* This salt crystallizes in thin plates soft and pliant, and of a pearly lustre. Its taste is astringent. Its is very soluble in water, and crystallizes with difficulty.

Sp. 9. *Alum.* This is a triple salt, of which there are four varieties, namely, 1. *Sulphate of alumina-and-potash;* 2. *Sulphate of alumina-and-ammonia;* 3. *Supersulphate of of ammonia-and-potash;* 4. *Supersulphate of alumina-and-ammonia.* The two last (especially the 3d) constitute the *alum* of commerce; the two first have been called *alum saturated with its earth,* or *aluminated alum.*

The composition of common alum was first ascertained by Vauquelin. It crystallizes in regular octahedrons. It is white, and semitransparent. Its taste is sweetish and astringent, and it reddens vegetable blues. It dissolves in about 16 parts of cold water. In a gentle heat it undergoes the watery fusion, and by continuing the heat it loses about 44 per cent. of water, and is called *calcined* or *burnt alum.* In a violent heat a portion of the acid is converted into sulphurous acid, and oxygen gas. This salt, according to the analysis of Vanquelin, is usually composed of

Sulphuric acid	30·52
Alumina	10·50
Potash	10·40
Water	48·58
	100·00

Alum sometimes contains a little sulphate of iron mixed with it, which injures its qualities as a mordant.

The *sulphates,* or two first varieties, may be formed by boiling alumina in a solution of alum. They are tasteless powders, insoluble in water, and not altered by exposure to the air.

Sp. 10. *Sulphate of Yttria.* This salt crystallizes in flat six-sided prisms. It is not altered by exposure to the air. Its taste is astringent and sweet. It has an amethyst red colour, and dissolves in about 30 parts of cold water. At a red heat it is perfectly decomposed.

Sp. 10. *Sulphate of Glucina.* This salt is colourless. It crystallizes in needles. Its taste is very sweet, and somewhat astringent. It is very soluble in water, and the solution does not readily crystallize. When heated it undergoes the watery fusion, and in a red heat is completely decomposed.

Sp. 12. *Sulphate of Zirconia.* This salt is usually in the form of a white powder; though it may be obtained also crystallized in needles. It is tasteless, and insoluble in water; not altered by exposure to the air, and easily decomposed by heat.

Sp. 13. *Sulphate of Lime.* This salt occurs native, and is distinguished by the names of *gypsum* and *selenite*. It is found crystallized in octahedrons, six-sided prisms, and in lenses. It has little or no taste. It dissolves in about 460 parts of cold water. It is not altered by exposure to the air. It dissolves in sulphuric acid. When heated it loses its water of crystallization. When mixed with a little lime, it is much used under the name of *plaster of Paris* for forming casts, moulds, &c.

Sp. 14. *Sulphate of Barytes.* This salt is found native, and distinguished by the names of *ponderous spar, heavy spar, baroselenite.* It occurs crystallized in tables with bevilled edges, in four-sided prisms, &c. It is white, tasteless, insoluble in water, but soluble in hot sulphuric acid. It melts when strongly heated into a white opake globule. When made into a cake with flour, and heated to redness, it is phosphorescent.

Sp. 15. *Sulphate of Strontian.* This salt, like the preceding, occurs native in considerable quantity. It is crystallized in rhomboidal prisms. It is white, tasteless, insoluble in water, but soluble in hot sulphuric acid. In most of its properties it resembles the preceding salt, but its specific grareous taste. It is insoluble in water, and when exposed to the air it is slowly converted into sulphate.

The following table exhibits the constituents of the sulphites as far as they have been ascertained.

Sulphites of	*Acid.*	*Base.*	*Water.*
Magnesia	100	41	115
Ammonia	100	48·3	18·3
Soda	100	58	164
Lime	100	97·9	10·5
Potash	100	125	4·6
Alumina	100	137·5	75
Barytes	100	151	5·1

GENUS IX. *Nitrates.*

All the salts belonging to this genus are soluble in water, and crystallize by cooling. When heated to redness, and charcoal powder thrown over them, a violent combustion is produced. Sulphuric acid disengages from them fumes of nitric acid. When heated they are decomposed and yield at first oxygen gas.

Sp. 1. *Nitrate of Potash or Nitre.* This salt, which is of great importance, is found in warm climates on the surface of the earth. It is collected and purified by solution and crystallization. Its crystals are six-sided prisms terminated by six-sided pyramids. Its taste is sharp, bitterish and cooling. It is very brittle. It dissolves in seven parts of cold water, and in less than its own weight of boiling water. Pure alcohol does not dissolve it. In a red heat it melts and congeals into an opake mass which has been called *mineral crystal*. When kept melted it gives out about the third of its weight of oxygen gas. It detonates most violently with charcoal. This salt constitutes the principal ingredient of gun powder, which is a mixture of about seventy-six parts nitre, fifteen charcoal, and nine sulphur. The constituents are ground to a fine powder, and then mixed together with great care. The goodness of the powder depends upon the intimate mixture. Those kinds of charcoal are pitched upon which absorb the least moisture from the air.

Sp. 2. *Nitrate of Soda.* This salt crystallizes in transparent rhombs differing but little from cubes. It has a cool sharp taste, and is rather more bitter than nitre. It dissolves in three parts of cold water, and in less than its weight of boiling water. When exposed to the air it rather attracts moisture. Its phenomena with combustibles and heat are the same as those of the preceding species.

Sp. 3. *Nitrate of Ammonia.* This salt crystallizes in six-sided prisms, terminated by six-sided pyramids. It has a very acrid, bitter, disagreeable taste. It dissolves in twice its weight of cold water, and in half its weight of boiling water. In the air it very speedily deliquesces. When heated it undergoes the watery fusion, but even after the water is driven off it continues liquid at the temperature of about 400°, boils, and is decomposed, being converted into water and *nitrous oxide* gas, in the proportion of about four parts gas to three parts water. When heated nearly to redness, it burns with a kind of explosion. Hence it was formerly called *nitrum flammans*.

Sp. 4. *Nitrate of Magnesia.* This salt crystallizes in rhomboidal prisms or small needles. Its taste is very bitter and disagreeable. It is soluble in little more than its weight of cold water. In the air it deliquesces. When heated it undergoes the watery fusion, and speedily assumes the form of a white powder. It scarcely detonates with combustible bodies.

Sp. 5. *Nitrate of Lime.* This salt crystallizes in six-sided prisms terminated by long pyramids. Its taste is very acrid and bitter. It dissolves in about the fourth part of its weight of cold water, and boiling water dissolves any quantity of it whatever. Boiling alcohol dissolves its own weight of it. It speedily deliquesces in the air. When heated it readily undergoes the watery fusion. When deprived of its water of crystallization it often has the property of shining in the dark. In this state it is called *Baldwin's phosphorus.*

Sp. 6. *Nitrate of Barytes.* This salt crystallizes in regular octahedrons, or in small brilliant plates. Its taste is hot, acrid and austere. It is soluble in about twelve parts of cold water. When thrown upon burning coals, it decrepitates and is converted into a dry mass. When strongly heated, the whole of its acid is dissipated and pure barytes obtained.

Sp. 7. *Nitrate of Strontian.* This salt crystallizes in regular octahedrons not unlike the crystals of nitrate of barytes. It has a strong pungent cooling taste. It is soluble in its own weight of cold water, and in little more than half its weight of boiling water. It is insoluble in alcohol. It deflagrates on hot coals. In a crucible it melts when heated. At a red heat it gives out its acid, and pure strontian remains behind. Combustibles thrown into it when red hot burn with a lively red flame.

Sp. 8. *Nitrate of Ammonia-and-magnesia.* This salt crystallizes in fine prisms. It has a bitter, acrid, ammoniacal taste. It dissolves in about eleven parts of cold water. In the air it gradually attracts moisture and deliquesces.

Sp. 9. *Nitrate of Alumina.* This salt crystallizes with difficulty into thin soft plates which have but little lustre. It has an acid and astringent taste, is very soluble in water and soon deliquesces when exposed to the air. When evaporated, it is readily converted into a gummy mass of the consistence of honey. It is easily decomposed by heat.

Sp. 10. *Nitrate of Ytria.* This salt scarcely crystallizes. Its taste is sweet and astringent. It speedily deliquesces in the air.

Sp. 11. *Nitrate of Glucina.* This salt may be obtained in the state of a powder, but not in crystals. Its taste is sweet and astringent. It is very soluble in water and speedily deliquesces in the air.

Sp. 12. *Nitrate of Zirconia.* This salt does not crystallize, but may be obtained in the state of a viscid mass which dries with difficulty. It has an astringent taste. It is very sparingly soluble in water, and seems indeed to be partially decomposed by that liquid. When heated it readily parts with its acid and is decomposed.

The following table exhibits the composition of the nitrates as far as it has been ascertained :—

Nitrate of	*Acid.*	*Base.*	*Water.*
Ammonia	100	40·38	35·1
Magnesia	100	47·64	
Lime	100	55·70	18·7
Soda	100	73·43	
Strontian	100	116·86	105.3
Potash	100	117·7	8·1
Barytes	100	178·12	34·3

GENUS X. *Nitrites.*

When the crystallized nitrates are exposed to a sufficient heat, they give out oxygen gas. If the process be stopped in time the salts still continue neutral. But the nature of the acid is obviously changed as it has lost oxygen. Hence by this process the nitrates are converted into nitrites. The properties of the nitrites have not hitherto been investigated, except the nitrite of potash, examined by Bergman and Scheele. It deliquesces when exposed to the air, and gives out nitrous fumes, when treated with any acid, even the acetic.

GENUS XI. *Oxymuriates.*

When oxymuriatic gas is passed through the alkalies and alkaline earths in a dry state, a combination takes place and saline substances are formed, to which the name of *oxymuriates* is given. But when the bases are dissolved or suspended in water, the oxymuriatic acid is decomposed and converted into hyperoxymuriatic and common muriatic acid. The oxymuriates have not, hitherto, been examined.

GENUS XII. *Hyperoxymuriates.*

This genus of salts was discovered by Berthollet. But except the first species, all the rest were nearly unknown till examined by Chenevix in 1802. They are formed by passing a current of oxymuriatic acid through the bases dissolved in water. When heated nearly to redness, they give out oxygen gas and are converted into muriates. When mixed with combustibles and heated, triturated or struck upon an anvil, they detonate with great violence.

Sp. 1. *Hyperoxymuriate of Potash.* This salt crystallizes in flat rhomboidal prisms of a silvery whiteness. Its taste is cooling, austere and disagreeable, somewhat analogous to that of nitre. It dissolves in 16 parts of cold, and 2½ of boiling water. It is not sensibly altered by exposure to the air. When heated nearly to redness, it gives out more than a third of its weight of oxygen gas. It detonates loudly when mixed with sulphur or phosphorus, and struck upon an anvil or triturated in a mortar. The experiment ought not to be tried with more than a grain of the mixture. It may be made into gunpowder with sulphur and charcoal, but it is liable to explode during the preparation.

Sp. 2. *Hyperoxymuriate of Soda.* This salt is not easily obtained pure, because it is as soluble in water as the muriate of soda, with which it is mixed in the preparation. It crystallizes in cubes. It produces a sensation of cold in the mouth, and has a taste different from that of common salt. It dissolves in about three parts of cold water. In the air it deliquesces slightly. It dissolves in alcohol.

Sp. 3. *Hyperoxymuriate of Ammonia.* This salt may be formed by mixing carbonate of ammonia with an earthy hyperoxymuriate. It is very soluble in water and alcohol, and is decomposed at a moderate temperature.

Sp. 4. *Hyperoxymuriate of Magnesia.* This salt resembles the hyperoxymuriate of lime in its properties.

Sp. 5. *Hyperoxymuriate of Lime.* This salt may be formed by passing a current of oxymuriatic acid gas through lime diffused in water, and boiling phosphate of silver in the solution, filtering and evaporating. Its taste is sharp and bitter. It is very deliquescent, and dissolves copiously in alcohol.

Sp. 6. *Hyperoxymuriate of Barytes.* This salt may be obtained in the same way as the preceding species. It is soluble in four parts of cold water.

Sp. 7. *Hyperoxymuriate of Strontian.* This salt may be prepared like the preceding. It crystallizes in needles, deliquesces, and is soluble in alcohol.

The following table exhibits a view of the constituents of the hyperoxymuriates, as far as has been ascertained.

Hyperoxymuriate of	*Acid.*	*Base.*	*Water.*
Magnesia	100	42·80	23·83
Soda	100	44·78	6·35
Lime	100	51·25	29·89
Strontian	100	56·52	60·87
Potash	100	67·24	4·30
Barytes	100	89·78	22·98

GENUS XIII. *Arseniates.*

When the salts belonging to this genus are heated along with charcoal powder, they are decomposed and arsenic sublimes.

Sp. 1. *Arseniate of Potash.* This salt does not crystallize. It deliquesces, and changes vegetable blues to green. The *superarseniate of potash* is a transparent white salt which crystallizes in four-sided prisms, terminated by four-sided pyramids. It is soluble in water, and gives a red colour to vegetable blues.

Sp. 2. *Arseniate of Soda.* This salt crystallizes in six-sided prisms. The superarseniate does not crystallize.

Sp. 3. *Arseniate of Ammonia.* This salt crystallizes in rhomboidal prisms. With an excess of acid it crystallizes in needles.

Sp. 4. *Arseniate of Magnesia.* This salt does not crystallize, but may be obtained in a solid gummy mass.

Sp. 5. *Arseniate of Lime.* This salt crystallizes, and is soluble in water.

Sp. 6. *Arseniate of Barytes.* This salt is insoluble in water, and cannot be crystallized.

Sp. 7. *Arseniate of Alumina.* This salt is a white powder insoluble in water.

Sp. 8. *Arseniate of Yttria.* This salt is likewise a white powder, which does not crystallize.

GENUS XIV. *Arsenites.*

The term *arsenite* has been applied to the combinations of white oxide of arsenic with the salifiable bases. The alkaline arsenites are yellow coloured masses with a nauseous odour not crystallizable, formerly called *livers of arsenic.* The earthy arsenites are white powders nearly insoluble in water.

GENUS XV. *Molybdates.*

If into a solution of a molybdate a cylinder of tin with some muriatic acid be put, the liquid gradually assumes a deep blue colour.

Sp. 1. *Molybdate of Potash.* This salt crystallizes in small rhomboidal plates. It is bright and has a metallic taste. It is soluble in hot water.

Sp. 2. *Molybdate of Soda.* This salt crystallizes, and is very soluble in water.

Sp. 3. *Molybdate of Ammonia.* This salt is soluble in water, and does not crystallize.

Sp. 4. *Molybdate of Magnesia.* This salt also is soluble in water, and does not crystallize.

Sp. 5. *Molybdate of Lime.* This is a white insoluble powder.

GENUS XVI. *Tungstates.*

These salts are combinations of yellow oxide of tungsten with the salifiable bases.

Sp. 1. *Tungstate of Potash.* This salt is soluble in water, deliquesces and does not crystallize. Its taste is metallic and caustic.

Sp. 2. *Tungstate of Soda.* This salt crystallizes in elongated hexahedral plates. Taste acrid and caustic. Soluble in four parts of cold, and two parts of boiling water.

Sp. 3. *Tungstate of Ammonia.* This salt crystallizes in needles or small plates. Its taste is metallic. It is soluble in water, and does not deliquesce.

Sp. 4. *Tungstate of Magnesia.* This salt crystallizes in small brilliant scales. It is soluble in water, and not altered by exposure to the air.

Sp. 5. *Tungstate of Lime.* This salt is found native. It is usually crystallized. The crystals are octahedrons. Colour yellowish grey, semi-transparent. It is insoluble in water, and not altered by exposure to the air.

Sp. 6. & 7. The tungstates of barytes and of alumina, are white insoluble powders scarcely examined.

GENUS XVII. *Chromates.*

This genus of salts has been but imperfectly examined. The salts have usually a yellow colour. The alkaline chromates and chromate of lime are soluble in water and crystallize; chromate of barytes appears to be insoluble.

GENUS XVIII. *Columbates.*

This genus of salts has been very imperfectly examined. We know only the columbate of potash which crystallizes in scales. Its taste is acrid and disagreeable.

ORDER II.

COMBUSTIBLE SALTS.

GENUS I. *Acetates.*

The acetates are all soluble in water. Heat decomposes them, driving off and destroying the acid. When mixed with sulphuric acid and distilled, acetic acid comes over, easily distinguished by its smell.

Sp. 1. *Acetate of Potash.* This salt is usually obtained in plates, but it crystallizes regularly in prisms. It has a sharp warm taste. It deliquesces in moist air, but in dry air undergoes but little alteration. It is soluble also in alcohol. When heated it melts, and in a high temperature is decomposed.

Sp. 2. *Acetate of Soda.* This salt crystallizes in striated prisms, not unlike those of sulphate of soda. It has a sharp taste, inclining to bitter. It dissolves in rather less than three times its weight of cold water. It is not affected by exposure to the air. When heated it loses its water of crystallization, and is decomposed.

Sp. 3. *Acetate of Ammonia.* This salt, called formerly *spirit of Mindererus*, cannot easily be crystallized by evaporation, but it may be obtained in needles by slow sublimation. Its taste is similar to that of a mixture of sugar and nitre. It is very deliquescent. It melts at 170°, and sublimes at about 250°.

Sp. 4. *Acetate of Magnesia.* This salt does not crystallize. It has a sweetish taste. It is very soluble both in water and alcohol. It deliquesces in the air.

Sp. 5. *Acetate of Lime.* This salt crystallizes in needles, and has a glossy appearance like satin. Its taste is bitter and acid. It is soluble in water, and not altered by exposure to the air.

Sp. 6. *Acetate of Barytes.* This salt crystallizes in fine, transparent, prismatic needles. Its taste is acid and somewhat bitter. It dissolves in little more than its weight of water, and rather effloresces in the air. Alcohol dissolves about $\frac{1}{100}$ of its weight of it.

Sp. 7. *Acetate of Strontian.* This salt crystallizes. Its taste is not unpleasant. It dissolves in little more than its weight of cold water. It gives a green colour to vegetable blues.

Sp. 8. *Acetate of Alumina.* This salt crystallizes in needles, is very deliquescent, and has an astringent taste.

Sp. 9. *Acetate of Yttria.* This salt crystallizes in six-sided plates of an amethyst red colour, and is not altered by exposure to the air.

Sp. 10. *Acetate of Glucina.* This salt does not crystallize, but yields a gummy mass. Its taste is sweet and astringent.

Sp. 11. *Acetate of Zirconia.* This salt does not crystallize, but may be obtained in the state of a powder which does not attract moisture from the air. It taste is astringent. It is very soluble in water and in alcohol.

The following table exhibits a view of the constituents of these salts, as far as they have been ascertained.

Acetates of	*Acid.*	*Base.*
Alumina	100	35·48
Magnesia	100	41·55
Ammonia	100	45·40
Lime	100	53·58
Soda	100	58·04
Strontian	100	89·80
Potash	100	108·45
Barytes	100	165·72

GENUS II. *Benzoates.*

This genus of salts has been so superficially examined, that a detailed description of the species cannot be given. All the benzoates examined are soluble in water, crystallize and have a sharp saline taste. The benzoates of ammonia and alumina deliquesce, the others do not. Most of the species form feather-shaped crystals.

GENUS III. *Succinates.*

This genus of salts is almost as little known as the preceding. Most of the succinates crystallize. Succinate of magnesia is an exception; and succinates of barytes and glucina, are nearly insoluble in water.

GENUS IV. *Moroxylates.*

Only two species of this genus have been examined, the moroxylates of lime and ammonia, both of which crystallize in needles, and are soluble in water.

GENUS V. *Camphorates.*

The salts belonging to this genus have usually a bitterish taste. When heated, they are decomposed, and the acid commonly sublimes. Before the blowpipe, they burn with a blue flame.

Sp. 1. *Camphorate of Potash.* This salt is white and transparent, and crystallizes in hexagons. It dissolves in 100 parts of cold, and in four parts of hot water. Alcohol also dissolves it, and burns with a deep blue flame. When heated it melts, and the acid is volatilized.

Sp. 2. *Camphorate of Soda.* This salt is white and transparent. Its crystals are irregular. It dissolves in rather more than 100 parts of cold, and in eight parts of hot water. It is soluble in alcohol. It effloresces slightly in the air.

Sp. 3. *Camphorate of Ammonia.* This salt does not readily crystallize. It is opake, and has a sharp bitterish taste. It dissolves in about 100 parts of cold, and three parts of hot water. It is soluble in alcohol. When heated it sublimes.

Sp. 4. *Camphorate of Magnesia.* This salt does not crystallize. It is white, opake, and has a bitter taste. It requires about 290 parts of water to dissolve it. Cold alcohol does not act on it, hot alcohol decomposes it, and dissolves the acid.

Sp. 5. *Camphorate of Lime.* This salt does not crystallize. Cold water dissolves very little of it; hot water dissolves about $\frac{1}{200}$th part. It is insoluble in alcohol. In the air it falls to powder. When heated it melts, and the acid is volatilized.

Sp. 6. *Camphorate of Barytes.* This salt does not crystallize, It has little taste. It is scarcely soluble in water or alcohol. It is not altered by exposure to the air. When heated it melts, and the acid is volatilized.

Sp. 7. *Camphorate of alumina.* This salt is a white powder, with an acid, bitter, astringent taste. It dissolves in about 200 parts of cold water, and in a much smaller quantity of hot water. Hot alcohol dissolves it readily.

GENUS VI. *Oxalates.*

The salts belonging to this genus are easily decomposed in a red heat; water, carbonic acid, carbonic oxids, carbureted hydrogen and charcoal are evolved, and the acid destroyed. The alkaline oxalates are soluble in water, and crystallize. They combine with an excess of acid, and form super-oxalates. The earthy oxalates are insoluble in water, or nearly so. Lime water occasions a precipitate in the solution of oxalates, provided there be no great excess of acid.

Sp. 1. *Oxalate of Potash.* This salt crystallizes in flat rhomboids. Its taste is cooling and bitter. It dissolves in thrice its weight of cold water, It absorbs a little moisture from the atmosphere.

Sp. 2. *Superoxalate of Potash.* This salt is extracted from sorrel, and usually sold under the name of the *essential salt of lemons.* Its crystals are small opake parallelopipeds. It has an acid, pungent, bitterish taste. It dissolves in about 10 times its weight of boiling water, but requires a much greater quantity of cold water. It is not altered by exposure to the air. It contains exactly double the quantity of acid which the oxalate of potash contains.

Sp. 3. *Quadroxalate of Potash.* This salt was lately discovered by Dr Wollaston, by digesting superoxalate of potash in nitric or muriatic acids. One half of the alkali is separated, and there remains behind a salt, which may be obtained in crystals, and which contains four times the proportion of acid that exists in oxalate of potash.

Sp. 4. *Oxalate of Soda.* This salt crystallizes, and has nearly the same taste with the oxalate of potash. When heated it falls to powder, being deprived of its water of crystallization.

Sp. 5. *Oxalate of Ammonia.* This salt crystallizes in four-sided prisms, terminated by dihedral summits. Its taste is bitter and unpleasant, somewhat similar to that of sal-ammoniac. 100 parts of cold water dissolve 4½ of this salt. It is insoluble in alcohol. When distilled, carbonate of ammonia is disengaged, a little acid sublimed, and some charcoal left behind.

Sp. 6. *Oxalate of Alumina.* This salt does not crystallize, and has a yellow colour. It has a sweet astringent taste, is soluble in water, and sparingly soluble in alcohol. It deliquesces in the air.

The remaining species are nearly insoluble in water.

Sp. 7. *Oxalate of Magnesia.* This is a tasteless white powder, not sensibly soluble in water; yet oxalate of ammonia does not occasion a precipitate when dropt into sulphate of magnesia.

Sp. 8. *Oxalate of Lime.* This is a white powder, insoluble in water, which makes its appearance when oxalate of ammonia is poured into any neutral salt with base of lime. It is tasteless, and dissolves readily in acids.

Sp. 9. *Oxalate of Barytes.* This is an insoluble, tasteless, white powder. With an excess of acid, it may be obtained crystallized in needles.

Sp. 10. *Oxalate of Strontian.* This is a white, insoluble, tasteless powder. The *superoxalate of strontian* is also insoluble. It contains just double the proportion of acid which the oxalate does.

or alcohol. It is not altered by exposure to the air. When heated it melts, and the acid is volatilized.

Sp. 7. *Camphorate of alumina.* This salt is a white powder, with an acid, bitter, astringent taste. It dissolves in about 200 parts of cold water, and in a much smaller quantity of hot water. Hot alcohol dissolves it readily.

GENUS VI. *Oxalates.*

The salts belonging to this genus are easily decomposed in a red heat; water, carbonic acid, carbonic oxids, carbureted hydrogen and charcoal are evolved, and the acid destroyed. The alkaline oxalates are soluble in water, and crystallize. They combine with an excess of acid, and form super-oxalates. The earthy oxalates are insoluble in water, or nearly so. Lime water occasions a precipitate in the solution of oxalates, provided there be no great excess of acid.

Sp. 1. *Oxalate of Potash.* This salt crystallizes in flat rhomboids. Its taste is cooling and bitter. It dissolves in thrice its weight of cold water, It absorbs a little moisture from the atmosphere.

Sp. 2. *Superoxalate of Potash.* This salt is extracted from sorrel, and usually sold under the name of the *essential salt of lemons.* Its crystals are small opake parallelopipeds. It has an acid, pungent, bitterish taste. It dissolves in about 10 times its weight of boiling water, but requires a much greater quantity of cold water. It is not altered by exposure to the air. It contains exactly double the quantity of acid which the oxalate of potash contains.

Sp. 3. *Quadroxalate of Potash.* This salt was lately discovered by Dr Wollaston, by digesting superoxalate of potash in nitric or muriatic acids. One half of the alkali is separated, and there remains behind a salt, which may be obtained in crystals, and which contains four times the proportion of acid that exists in oxalate of potash.

Sp. 4. *Oxalate of Soda.* This salt crystallizes, and has nearly the same taste with the oxalate of potash. When heated it falls to powder, being deprived of its water of crystallization.

Sp. 5. *Oxalate of Ammonia.* This salt crystallizes in four-sided prisms, terminated by dihedral summits. Its taste is bitter and unpleasant, somewhat similar to that of sal-ammoniac. 100 parts of cold water dissolve 4½ of this salt. It is insoluble in alcohol. When distilled, carbonate of ammonia is disengaged, a little acid sublimed, and some charcoal left behind.

Sp. 6. *Oxalate of Alumina.* This salt does not crystallize, and has a yellow colour: It has a sweet astringent taste, is soluble in water, and sparingly soluble in alcohol. It deliquesces in the air.

The remaining species are nearly insoluble in water.

Sp. 7. *Oxalate of Magnesia.* This is a tasteless white powder, not sensibly soluble in water; yet oxalate of ammonia does not occasion a precipitate when dropt into sulphate of magnesia.

Sp. 8. *Oxalate of Lime.* This is a white powder, insoluble in water, which makes its appearance when oxalate of ammonia is poured into any neutral salt with base of lime. It is tasteless, and dissolves readily in acids.

Sp. 9. *Oxalate of Barytes.* This is an insoluble, tasteless, white powder. With an excess of acid, it may be obtained crystallized in needles.

Sp. 10. *Oxalate of Strontian.* This is a white, insoluble, tasteless powder. The *superoxalate of strontian* is also insoluble. It contains just double the proportion of acid which the oxalate does.

Sp. 11. *Oxalate of Yttria.* This is also a white, insoluble, tasteless powder.

The following table exhibits the composition of the oxalates, as far as ascertained:

Oxalates of	*Acid.*	*Base.*
Ammonia	100	34·12
Magnesia	100	35·71
Soda	100	57·14
Lime	100	60·00
Potash	100	122·86
Strontian	100	151·51
Barytes	100	142·86

GENUS VII. *Mellates.*

This genus of salts has been but imperfectly examined. The alkaline mellates are soluble in water, and crystallize. The earthy do not appear soluble, and therefore are usually in the state of flaky powders.

GENUS VIII. *Tartrates.*

These salts, when exposed to a red heat, are decomposed, and the base remains in the state of a carbonate, usually mixed with charcoal. The earthy tartrates are nearly insoluble in water; the alkaline are soluble; but they combine with an excess of acid, and are converted into supertartrates, which are much less soluble than the tartrates. They readily combine with another base, and form triple salts.

Sp. 1. *Tartrate of Potash.* Of this salt there are two varieties. The first, containing an excess of acid, is usually called *tartar.* The second, which is neutral, is called *tartrate of potash*, and formerly it was called *soluble tartar,* from its greater solubility in water.

Variety 1. *Supertartrate of Potash,* or *Tartar.* This salt deposites itself on the sides of casks in which wine is kept. It is purified by solution, and evaporations. It is from it that tartaric acid is usually obtained. Its crystals are small and irregular. Its taste is acid, and rather unpleasant. It is brittle, and soluble in about 60 parts of cold water. It is not altered by exposure to the air, but when kept dissolved in water is gradually decomposed. When distilled, it gives out a great deal of heavy inflammable air, and carbonic acid gas; and an acid liquor is obtained, formerly called *pyrotartarous acid,* but now known to be merely the acetic, contaminated with a little empyreumatic oil. The tartar of commerce contains about 5 per cent. of tartrate of lime.

Variety 2. *Tartrate of Potash.* This salt may be formed by saturating the preceding with potash or its carbonate. Its crystals are flat four-sided rectangular prisms, terminated by dihedral summits. It dissolves in about its own weight of cold water. Its taste is an unpleasant bitter.

Sp. 2. *Tartrate of Soda.* This salt crystallizes in needles. It is soluble in its own weight of cold water. It it capable of forming a *supertartrate.*

Sp. 3. *Tartrate of Ammonia.* This salt crystallizes in small polygonal prisms. It has a cooling bitter taste. It is very soluble in water. It is said also to be capable of forming a *supertartrate.*

Sp. 4. *Tartrate of Potash-and-Soda.* This salt may be formed by saturating *tartar* with carbonate of soda. It was formerly called *Rochelle salt*, and *salt of Seignette.* It crystallizes in large irregular prisms. It has a bitter taste, is very soluble in water, and effloresces when exposed to the air.

Tartar forms also a triple salt when neutralized by ammonia.

Sp. 5. *Tartrate of Magnesia.* This salt is insoluble in water, unless it contains an excess of acid. In that case it crystallizes in six-sided prisms.

Tartar forms a triple salt when neutralized by magnesia.

Sp. 6. *Tartrate of Lime.* This salt is a white powder insoluble in cold water. It is difficult to free it from water by heat. An excess of acid renders it soluble.

Tartar forms a triple salt when neutrallized by lime.

Sp. 7. *Tartrate of Barytes.* This salt is soluble; but its properties have not been ascertained.

Sp. 8. *Tartrate of Strontian.* This salt crystallizes in triangular tables. It is insipid, and nearly insoluble in water.

Tartar forms triple salts when neutralized by barytes and strontian.

Sp. 9. *Tartrate of Alumina.* This salt does not crystallize, but forms a gummy mass soluble in water. Its taste is astringent. It does not deliquesce.

Tartar forms a triple salt when neutrallized by alumina.

Sp. 10. *Tartrate of Yttria.* This salt is soluble in water, but not to a great degree.

The following table exhibits the composition of the tartrates as far as it has been ascertained.

Tartrates of	*Acid.*	*Base.*
Alumina	100	31·06
Magnesia	100	36·30
Ammonia	100	39·67
Lime	100	45·00
Soda	100	50·80
Strontian	100	78·60
Potash	100	72·41
Barytes	100	131·41

GENUS IX. *Citrates.*

When barytes is poured into a solution of a citrate a precipitate appears. They are decomposed also by the mineral acids, and by oxalic and tartaric acids. When distilled, they yield traces of acetic acid. When kept dissolved in water the acid is gradually decomposed.

Sp. 1. *Citrate of Potash.* This salt does not crystallize easily. It is very soluble in water, and readily deliquesces.

Sp. 2. *Citrate of Soda.* This salt cystallizes in six-sided prisms, not terminated by pyramids. Its taste is salt and cooling, but mild. It dissolves in less than twice its weight of water. When exposed to the air it effloresces slightly.

Sp. 3. *Citrate of Ammonia.* This salt crystallizes in elongated prisms. Its taste is cooling, and moderately saline. It is very soluble in water.

Sp. 4. *Citrate of Magnesia.* This salt is very soluble in water. It does not crystallize.

Sp. 5. *Citrate of Lime.* This is a white powder scarcely soluble in water, but with an excess of acid it may be obtained in crystals.

Sp. 6. *Citrate of Barytes.* This salt is very imperfectly soluble in water. It may be obtained in the state of a white powder, or of silky flakes.

Sp. 7. *Citrate of Strontian.* This salt is soluble in water. It may be obtained in crystals; and is said to resemble in its properties, the oxhalate or tartrate of strontian.

GENUS X. *Kinates.*

Only one species of this genus of salts has been hitherto examined, namely *kinate of lime,* obtained by macerating yellow peruvian bark in water, and evaporating the solution. It is white, crystallizes in rhomboidal plates, dissolves in about five times its weight of cold water, and is insoluble in alcohol. When heated sufficiently, it is decomposed, and the acid destroyed.

GENUS XI. *Saccolates.*

These salts have hitherto been too superficially examined to admit of description. The alkaline saccolates are soluble in water, but the earthy are insoluble in that liquid.

GENUS XII. *Sebates.*

From the observations of Berzelius, it appears that the sebates approach very nearly to the benzoates in their properties.

GENUS XIII. *Urates.*

For the best account of these salts we are indebted to Dr

Henry. They are white powders destitute of taste, and imperfectly soluble in water. Urate of ammonia is the most soluble, and urate of barytes the least soluble.

GENUS XIV. *Malates.*

This genus of salts has also been imperfectly investigated. The alkaline malates are soluble in water, and deliquesce in the air. Malates of barytes and lime are nearly insoluble, but the latter combines with an excess of acid, and forms a supermalate of lime, which dissolves in water. This last salt is common in the vegetable kingdom. Malate of strontian dissolves in water, and malate of magnesia is very soluble in that liquid.

GENUS XV. *Formiates.*

These salts resemble the acetates in their properties. But they have been only superficially examined.

GENUS XVI. *Suberates.*

These salts have a bitter taste. They are all soluble in water, except the suberate of barytes. The earthy suberates scarcely crystallize. Most of these salts have an excess of acid.

GENUS XVII. *Gallates.*

The gallic acid seems scarcely capable of forming permanent salts with the salifiable bases. When the alkalies are dropt into a solution of gallic acid, it assumes a green colour. When the liquid is evaporated, the acid seems to be decomposed. Gallic acid occasions a blue or a red colour, when dropt into lime, barytes or strontian water.

Genus XVIII. *Prussiates.*

The prussic acid combines with the salifiable bases, but the compounds have little permanency, as the acid is separated by mere exposure to the air, or by a heat of 120°. Hence these salts have been but little examined. It is capable of combining with an alkali or earth, and with a metallic oxide at the same time, and of forming triple salts, which have a great deal of permanency. The oxide of iron is the metallic oxide usually present. Of all these salts the most important is the *prussiate of potash-and-iron*, or the *triple prussiate of potash*, as it is in common use as a reagent. It crystallizes in cubes or parallelopipeds. It has a yellow colour, and is semi-transparent. It contains about one-fourth of its weight of oxide of iron. It has a bitter taste, and is insoluble in alcohol, though soluble enough in water.

Sect. II. *Of Metalline Salts.*

Acids combine only with the oxides of metals; they seem incapable of uniting with metals themselves. Now most metals form more than one oxide, and acids are usually capable of combining with two oxides at least of the same metal. The properties of the salt vary a good deal according to the state of oxydizement of the oxide. Thus muriatic acid combined with the protoxide of mercury forms a salt insoluble in water, and which acts merely as a cathartic when taken internally. The same acid combined with the peroxide of mercury forms a salt which is soluble in water, and constitutes one of the most virulent poisons known. To distinguish the state of oxidizement of the metal in these salts therefore is necessary. At present I shall satisfy myself with denoting those metalline salts that contain protoxides by the usual name; while to the names of those that contain a peroxide the syllables *oxy* will be prefixed. Thus *muriate of mercury* is the compound of muratic acid and protoxide of mercury; *oxymuriate of mercury* is the compound of the same acid and peroxide of mercury. As there are twenty-seven metals, it is obvious that the genera of metalline salts are twenty-seven.

GENUS I. *Salts of Gold.*

The salts of gold are soluble in water, and the solution has a yellow colour. Triple prussiate of potash occasions a white precipitate in them, and the infusion of nutgalls gives them a green colour, and occasions a brown precipitate which is gold reduced. A plate of tin or muriate of tin occasions a purple precipitate. Sulphate of iron precipitates the gold in the metallic state.

Sp. 1. *Muriate of Gold.* This salt is easily obtained by dissolving gold in a mixture of one part nitric and four parts muriatic acid. The solution takes place speedily, and with effervescence. It has a yellow colour, and when sufficiently concentrated, lets fall small yellow crystals of muriate of gold. They are four-sided prisms or truncated octahedrons, and exceedingly deliquescent. The taste of this salt is acerb with a little bitterness. It tinges the skin of an indelible purple colour. It dissolves readily in alcohol, and seems more soluble in ether than in water. Almost all the metals throw down the gold from this salt, either in the metallic state or in that of a purple oxide. Hydrogen, phosphorus and sulphurous acid, produce the same effect by depriving the gold of its oxygen. Murate of tin occasions a beautiful powder called *purple of cassius.* It is employed as a paint, and to give a red colour to glass and porcelain. According to Proust, it is a compound of three parts of the oxide of tin, and one part of gold in the metallic state. But it seems more likely that the gold is in the state of protoxide.

Sp. 2. *Nitrate of Gold.* Nitric acid containing a considerable proportion of nitrous gas in solution, dissolves gold, especially if it be much divided, as is the case in gold leaf. The solution has an orange colour, and cannot be evaporated to dryness without decomposition.

The other salts of gold have not hitherto been examined.

GENUS II. *Salts of Platinum*

The solution of these salts in water has a brown or yellowish brown colour. No precipitate is produced by prussiate of potash or infusion of nutgalls. Sal-ammoniac occasions a copious yellow-coloured precipitate.

Sp. 1. *Nitrate of Platinum.* Nitric acid does not act upon platinum, but it dissolves its peroxide, and forms a salt not hitherto examined.

Sp. 2. *Muriate of Platinum.* This salt is obtained by dissolving platinum in aqua regia, and evaporating the solution, which is of a dark brown colour and opake. Small irregular crystals of muriate of platinum may be obtained, not more soluble in water than sulphate of lime. This salt has a disagreeable astringent metallic taste. Heat drives off the acid, and reduces the oxide to the metallic state.

The properties of the remaining species have been but imperfectly examined. Potash and ammonia are capable of combining with the salts of platinum and forming compounds very little soluble in water. Hence a precipitate takes place when these alkalies are poured into solutions containing platinum.

GENUS III. SALTS OF SILVER.

The nitric is the only acid which dissolves silver with facility, but they all combine with its oxides and form salts, most of which are but sparingly soluble in water. When the salts of silver are exposed to the action of the blow-pipe on charcoal, a globule of silver is obtained. Muriatic acid or a muriate occasions a white precipitate in their solutions which becomes black when exposed to the light. The prussiates occasion a white precipitate, and the hydrosulphuret of potash a black precipitate in these solutions.

Sp. 1. *Nitrate of Silver.* There are two species of this salt; the first, which has been long known, is an *oxynitrate;* the second, recently discovered by Proust, is a *nitrate.*

1. *Oxynitrate.* Nitric acid dissolves silver with facility, nitrous gas being emitted. The solution is colourless and transparent; very heavy and very caustic. It tinges the skin of an indelible black, and is often used as a cautery. When evaporated sufficiently it deposites crystals of oxynitrate of silver. They are usually in thin plates, transparent, and have an intensely bitter and metallic taste. It does not deliquesce, but becomes brown in a strong light. When heated, it readily melts, and congeals, when cold, into a grey mass crystallized in needles. In this state it is cast into small cylinders, and used under the name of *lunar caustic* by Surgeons, to open ulcers, and destroy fungous excrescences. It detonates when heated with combustibles, or when struck with phosphorus upon an anvil, and the silver is reduced. A moderate heat disengages the acid, and reduces the silver to the metallic state. It is composed of about seventy peroxide of silver, and thirty nitric acid.

2. *Nitrate.* This salt may be formed by boiling powder of silver in a saturated solution of oxynitrate of silver. A

pale yellow coloured liquid is obtained, which contains nitrate in solution. This salt is exceedingly soluble in water, and is not easily crystallized. When sufficiently evaporated, it congeals entirely into a solid mass. When exposed to the air, or mixed with nitric acid, it speedily absorbs oxygen, and is converted into oxynitrate.

Sp. 2. *Hyperoxymuriate of Silver.* This salt may be obtained by boiling phosphate of silver in hyperoxymuriate of alumina. It is soluble in two parts of warm water; as the solution cools it crystallizes in small rhomboids, opake and dull like nitrate of lead. It is soluble in alcohol. When exposed to a moderate heat, oxygen gas is given out and muriate of silver remains. When mixed with sulphur, and struck upon an anvil, it detonates with prodigious violence.

Sp. 3. *Muriate of Silver.* This salt is easily obtained, by pouring common salt into a solution of nitrate of silver. It is at first a heavy white curdy precipitate, but it soon blackens when exposed to the air. It is insoluble in water. When heated to about 500°, it melts into a grey coloured semi-transparent mass, having some resemblance to horn, and formerly called *luna cornea.* When heated with potash, or when boiled with water and iron filings, it is decomposed, and the silver reduced to the metallic state. It dissolves in ammonia; it is likewise soluble in muratic acid, and by that means may be obtained in octahedral crystals. It is composed of about eighteen acid, and eighty-two peroxide of silver. One hundred parts of dry muriate of silver contain about 75·6 parts of pure silver.

Sp. 4. *Sulphate of Silver.* This salt may be formed by boiling powder of silver in sulphuric acid. A white mass is obtained, soluble in diluted sulphuric acid, and yielding crystals by evaporation. The crystals are small prisms. They dissolve in about eighty-seven parts of water. They dissolve also in nitric acid. They melt when heated, and are easily decomposed, the silver being reduced. It is composed of about 17·4 acid and 82·6 peroxide of silver.

Sp. 5. *Sulphite of Silver.* This salt may be obtained by mixing sulphite of ammonia and nitrate of silver. It is a white powder, scarcely soluble in water, and having an acrid metallic taste. In the light it becomes brown. When heated it is decomposed, and the silver reduced.

Sp. 6. *Phosphate of Silver.* This is a white powder insoluble in water, but soluble in nitric acid.

Sp. 7. *Carbonate of Silver.* This is a white insoluble powder, which becomes black when exposed to the light.

Sp. 8. *Fluate of Silver.* This is a white powder insoluble in water.

Sp. 9. *Borate of Silver.* This likewise is a white insoluble powder.

Sp. 10. *Acetate of Silver.* This salt crystallizes in small prisms, easily soluble in water. When heated, it swells and yields a portion of ethereal liquor. The silver is reduced.

Sp. 11. *Benzoate of Silver.* This salt is soluble in water, and does not deliquesce.

Sp 12. *Saccinate of Silver.* This salt crystallizes in thin oblong radiated prisms.

Sp. 13. *Oxalate of Silver.* This is a white powder, scarcely soluble in water, insoluble in alcohol, but soluble in nitric acid.

Sp. 14. *Tartrate of Silver.* This salt is soluble in water.

Sp. 15. *Citrate of Silver.* This salt is insoluble in water. It is decomposed by nitric acid.

Sp. 16. *Saccolate of Silver.* A white insoluble powder.

Sp. 17. *Malate of Silver.* A white powder.

Sp. 18. *Arseniate of Silver.* An insoluble brown powder.

Sp. 19. *Chromate of Silver.* A beautiful crimson powder which becomes purple when exposed to the light.

Sp. 20. *Molybdate of Silver.* A white flaky powder.

GENUS IV. *Salts of Mercury.*

Mercurial salts when strongly heated are volatilized, and traces of mercury may sometimes be observed. The prussiates occasion in them a white precipitate, hydrosulphuret of potash, a black precipitate, and infusion of nutgalls an orange yellow precipitate.

Sp. 1. *Nitrate of Mercury.* There are two species of this salt, first correctly distinguished by Bergman, namely the *nitrate* and *oxynitrate.*

1. *Nitrate.* This salt is obtained by dissolving mercury in diluted nitric acid without the assistance of heat. The solution is colourless, very heavy and caustic. It tinges the skin indelibly black. It crystallizes in transparent octahedrons having their angles truncated. Sulphurated hydrogen gas, passed through the solution of this salt, reduces the mercury which separates in combination with sulphur. Muriate of tin throws down the base in the state of running mercury.

2. *Oxynitrate.* This salt is formed when nitric acid is made to dissolve mercury with the assistance of heat; provided an excess of mercury be not present. By continuing the heat, the solution passes into a yellow coloured crystalline mass. When diluted with water, a white or yellow powder separates which is a *suboxynitrate of mercury.*

Sp. 2. *Hyperoxymuriate of Mercury.* Mr Chenevix obtained this salt by passing a current of oxymuriatic acid through water, in which red oxide of mercury was diffused.

By evaporating the solution, crystals of *oxymuriate* and *hyperoxymuriate of mercury* were deposited. The latter were picked out and purified by a subsequent crystallization. This salt is soluble in about four parts of water.

Sp. 3. *Muriate of Mercury.* Of this salt there are two species, both long known, namely the *oxymuriate* and *muriate:* Both are of great importance.

1. *Oxymuriate.* This salt is usually called *corrosive sublimate,* or *corrosive muriate of mercury.* It was known to the alchymists. A vast number of methods of preparing it have been made public. The most common method is to mix together equal weights of dry oxynitrate of mercury, decrepitated common salt, and calcined sulphate of iron. One-third of a matrass or phial is filled with this mixture. The vessel is placed in a sand-bath, and gradually heated to redness. A cake of oxymuriate of mercury sublimes into the upper part of the vessel. It may be formed directly by dissolving red oxide of mercury in muriatic acid.

It has usually the form of a white semi-transparent cake composed of small prisms. Its specific gravity is 5·1398. Its taste is excessively acrid and caustic, and it leaves for a long time a very disagreeable styptic metallic impression on the tongue. It is one of the most virulent poisons known. It is soluble in about 20 parts cold and 3 parts boiling water. Alcohol dissolves nearly half its weight of it. It is not altered by exposure to the air. When heated it sublimes very readily, and the fumes are very dangerous when inhaled. It is soluble in sulphuric, nitric and muriatic acids, decomposed by the alkalies, and precipitated of a brick red colour. The alkaline earths likewise decompose it, and ammonia forms with it a triple compound. It is composed of about 19 parts of acid and 81 of peroxide of mercury.

2. *Muriate.* This salt is distinguished by the names of *calomel* and *mercurius dulcis.* It is prepared by triturating

four parts of oxymuriate of mercury, and three parts of mercury in a mortar, and then subliming the mixture in a matrass. It is a dull white mass, which becomes yellowish when reduced to powder. When slowly sublimed, it crystallizes in four-sided prisms, terminated by pyramids. Its specific gravity is 7·1758. It is insoluble in water. It is tasteless. When rubbed in the dark it phosphoresces. It requires a higher temperature to sublime it than oxymuriate of mercury. Oxymuriatic acid and nitric acid convert it into oxymuriate. It is composed of about 11 acid and 89 protoxide of mercury.

Sp. 4. *Sulphated Mercury.* Of this salt, likewise, there are two species, the *sulphate* and *oxysulphate*.

1. *Sulphate.* This salt may be obtained by boiling over mercury, sulphuric acid diluted with its own bulk of water. Very little sulphurous acid gas is disengaged. By evaporation the salt is obtained in small prismatic crystals. It dissolves in 500 parts of cold water, and is not altered by exposure to the air. The alkalies throw down a dark-coloured sub-sulphate of mercury, when poured into a solution of this salt. The sulphate of mercury is composed of 12 acid, 83 protoxide and 5 water.

2. *Oxysulphate.* When three parts of sulphuric acid are boiled on two parts of mercury, the whole, by continuing the heat, is converted into *oxysulphate*. This salt crystallizes in small prisms. When neutral, its colour is a dirty white; but, when in the state of *super-oxysulphate,* it is of a fine white. The neutral salt is not altered in the air, the super-oxysulphate deliquesces. It is composed of 31·8 acid, 63·8 peroxide, 4·4 water. When water is poured upon this salt, it is decomposed and converted into *super-oxysulphate* which dissolves, and *sub-oxysulphate,* which remains in the state of a beautiful yellow powder. This sub-salt is used as a pig-

ment, and was formerly known by the name of *turpeth mineral.* It is composed of 15 acid and 85 peroxide.

Sp. 5. *Phosphate of Mercury.* This salt may be formed by mixing together the solutions of nitrate of mercury and phosphate of soda. It is a white powder, insoluble in water, lately introduced into medicine, and composed of 28·5 acid, 71·5 peroxide.

There seems to be no such salt as *phosphite of mercury.*

Sp. 6. *Carbonate of Mercury.* A white insoluble powder.

Sp. 7. *Fluate of Mercury.* A white insoluble powder.

Sp. 8. *Borate of Mercury.* A yellow insoluble powder.

Sp. 9. *Acetated Mercury.* Of this salt there are two species, the *acetate* and *oxacetate.*

1. *Acetate.* This salt may be obtained by mixing together solutions of nitrate of mercury and acetate of potash. Its crystals are plates of a silvery whiteness. It has an acrid taste, is insoluble in alcohol, and scarcely soluble in water.

2. *Oxacetate.* This salt may be formed by dissolving red oxide of mercury in acetic acid. It is a yellow mass, which does not crystallize, and soon deliquesces in the air.

Sp. 10. *Succinate of Mercury.* This salt crystallizes, and is soluble in water.

Sp. 11. *Benzoate of Mercury.* A white powder, insoluble in water, and very sparingly soluble in alcohol.

Sp. 12. *Oxalate of Mercury.* A white powder, scarcely soluble in water, which blackens when exposed to the light. It detonates when heated.

Sp. 13. *Mellate of Mercury.* A white powder.

Sp. 14. *Tartrate of Mercury.* An insoluble white powder, becoming yellow when exposed to the air.

Sp. 15. *Citrate of Mercury.* A white mass, scarcely soluble in water.

Sp. 16. *Prussiate of Mercury.* This salt may be formed by boiling red oxide of mercury and prussian blue in water.

It crystallizes in four-sided prisms, terminated by four-sided pyramids. Its taste is acrid and metallic. It is white, and soluble in water.

Sp. 17. *Arseniate of Mercury*. A yellow insoluble powder.

Sp. 18. *Molybdate of Mercury*. A white flaky powder.

Sp. 19. *Chromate of Mercury*. An insoluble powder, of a fine purple colour.

GENUS V. *Salts of Palladium.*

The salts of this metal are almost all soluble in water, and the solution has a fine red colour. Prussiate of potash occasions a dirty yellowish brown precipitate, hydrosulphuret of potash, and the alkalies an orange-yellow precipitate when poured into solutions of these salts. Neither nitrate of potash nor sal ammoniac occasions any precipitate in them. Nitric, muriatic and sulphuric acid digested on palladium acquire a red colour. But the true solvent of that metal is nitro-muriatic acid. The salts of palladium are not yet sufficiently known to admit of a particular description.

GENUS VI. *Salts of Rhodium.*

The solutions of these salts are red. Prussiate of potash, hydrosulphuret of potash, sal ammoniac, and alkaline carbonates occasion no precipitate in them. But the pure alkalies throw down a yellow powder, soluble in an excess of alkali.

GENUS VII. *Salts of Iridium.*

These salts are soluble in water. The solution is at first green, but becomes red when concentrated in an open vessel. Neither prussiate of potash nor infusion of nutgalls occasion any precipitate, but they render the solutions of iridium colourless.

GENUS VIII. *Salts of Osmium.*

This genus of salts is still entirely unknown.

GENUS IX. *Salts of Copper.*

Most of these salts are soluble in water. The solution is blue or green, or at least it acquires these colours when exposed to the air. When ammonia is poured into these solutions, they assume a deep blue colour. Prussiate of potash occasions a greenish yellow precipitate, hydrosulphuret or potash a black precipitate, and gallic acid a brown precipitate in these solutions. A plate of iron or zinc put into these solutions precipitates the copper in the metallic state.

Sp. 1. *Nitrate of Copper.* Nitric acid attacks copper with some violence, nitrous gas is emitted, and the metal dissolved. By evaporation the salt crystallizes in parallelopipeds. It has a blue colour, its taste is acrid and metallic, and it is exceedingly caustic. It is very soluble in water, and speedily deliquesces in the air. When heated it undergoes the watery fusion ; and, if the heat be increased, the acid is driven off and the black oxide of copper remains in a state of purity. It detonates feebly on burning coals. It detonates when mixed with phosphorus and struck upon an anvil. When moistened and wrapt up in tin-foil, it sets the tin on fire. It is composed of 16 acid, 67 oxide and 17 water.

Sp. 2. *Hyper-oxymuriate of Copper.* This salt may be formed by passing a current of oxymuriatic acid through water, containing oxide of copper diffused through it.

Sp. 3. *Muriated Copper.* Of this salt there are two species, the *muriate* and *oxymuriate.*

1. *Oxymuriate.* This salt may be obtained by dissolving copper in nitro-muriatic acid, and evaporating the solution. Its crystals are rectangular parallelopipeds of a grass-green colour. It is very acrid and caustic. It is very soluble in water, and soon deliquesces in the air. In a moderate heat it melts. If the heat be increased, oxymuriatic acid is disengaged, and muriate of copper remains. This salt is composed of 24 acid, 40 peroxide, 36 water.

2. *Muriate.* This salt was discovered by Proust. It may be formed by putting copper filings into liquid oxymuriate of copper in a well-stopped phial, or by mixing equal weights of black oxide of copper and copper in powder, and dissolving them in muriatic acid in a well-stopped phial. It crystallizes in octahedrons. Its solution in water is colourless; when diluted, a white powder precipitates, which is a submuriate of copper. When exposed to the air, it is very speedily converted into oxymuriate. It is composed of 24·75 acid, 70·25 protoxide, 5 water.

Sp. 4. *Sulphate of Copper.* This salt has been long known, and in commerce is distinguished by the names of *blue vitriol* or *blue copperas.* It crystallizes in oblique parallelopipeds, has a blue colour, a styptic metallic taste, and is employed as a caustic. It is soluble in about four parts of cold water. When exposed to the air, it effloresces very slightly. By heat it is decomposed, and black oxide of copper remains. It reddens vegetable blues, and is, in fact, a supersulphate. The real sulphate crystallizes in four-sided prisms, terminated by pyramids. This salt is composed of 33 acid, 32 oxide, and 35 water.

Sulphuric acid does not seem capable of combining with protoxide of copper.

Sp. 5. *Sulphite of Copper.* When sulphite of soda and sulphite of copper are mixed, whitish green crystals of sulphite of copper are deposited. They are sparingly soluble in water.

Sp. 6. *Phosphate of Copper.* A bluish green powder, insoluble in water.

Sp. 7. *Carbonate of Copper.* A beautiful apple green powder, insoluble in water. It is often found native, and is distinguished by mineralogists by the name of *malachite.*

Sp. 7. *Fluate of Copper.* This salt crystallizes in cubes of a blue colour.

Sp. 8. *Borate of Copper.* A green powder, scarcely soluble in water.

Sp. 9. *Acetate of Copper.* This salt was known to the ancients. It is sometimes called *verdigris.* Though that name is more frequently applied to a *subacetate* of copper. It crystallizes in four-sided truncated pyramids. Its colour is a beautiful bluish green. Its taste is metallic, and nauseous; and like all the salts of copper it is poisonous. It is sparingly soluble in cold water, but boiling water dissolves about one-third of its weight of it. It is soluble also in alcohol. When exposed to the air it effloresces. When distilled, it yields acetic acid in considerable quantity. It is composed, according to Proust, of 61 acid and water, and 39 oxide of copper.

Sp. 11. *Succinate of Copper.* Small green crystals, not yet examined.

Sp. 12. *Benzoate of Copper.* Deep green crystals, sparingly soluble in water, and insoluble in alcohol.

Sp. 13. *Oxalate of Copper.* A green coloured salt, scarcely soluble in water.

Sp 14 *Tartrate of Copper.* Bluish green crystals, sparingly soluble in water.

Sp. 15. *Citrate of Copper.* Light green crystals.

Sp. 16. *Arseniate of Copper.* This salt is precipitated in the state of a bluish white powder, when arseniate of potash is poured into sulphate of copper. It is insoluble in water, unless it contains an excess of acid. It has been found native in Cornwall, in crystals, and has been analyzed by Chenevix. There are five varieties of it, differing in the proportion of acid and oxide, in the figure of their crystals and in colour.

The oxide of copper likewise combines with white oxide of arsenic, and forms a green powder, usually known by the name of *Scheele's green.*

GENUS X. *Salts of Iron.*

Most of the salts of iron are soluble in water; the solution has a green, or yellowish, or reddish colour, according to the state of oxydizement of the iron. Prussiate of potash throws down from these solutions a blue powder, or at least it becomes blue when exposed to the air. Hydrosulphuret of potash occasions a black precipitate. Gallic acid and the infusion of nut galls, throws down a black or purple precipitate.

Sp. 1. *Nitrate of Iron.* Diluted nitric acid acts with great energy upon iron, a gas being extricated, which is a mixture of nitrous gas and nitrous oxide. There are two varieties of this salt.

1. *Nitrate.* This salt may be formed by dissolving iron in nitric acid of the specific gravity 1·16. The action is slow and little gas is extricated. The iron is in the state of black oxide. The solution cannot be heated or concentrated without converting the iron into red oxide.

2. *Oxynitrate.* This salt may be formed by concentrating the preceding. The liquid assumes a red colour, and the red oxide of iron at last precipitates. The salt may be obtained in crystals, by keeping nitric acid in contact with black oxide of iron. The oxide gradually dissolves and four-

sided prisms, nearly colourless are gradually formed. They deliquesce in the air.

Sp. 2. *Hyperoxymuriate of iron.* This salt may be formed by passing a current of oxymuriatic acid through water, having red oxide of iron mixed with it.

Sp. 3. *Muriated Iron.* Of this salt there are two species, the *muriate* and *oxymuriate.*

1. *Muriate.* This salt may be formed by dissolving iron filings in muriatic acid, without the contact of the external air. The solution is green, and yields green coloured crystals very soluble in water. The solution absorbs nitrous gas in great abundance. When exposed to the air it absorbs oxygen, and the salt is converted into oxymuriate.

2. *Oxymuriate.* This salt may be formed by exposing the preceding to the atmosphere, or by dissolving red oxide of iron in muriatic acid. The solution has a dark brown colour; the salt does not crystallize, but when evaporated to dryness leaves a yellow coloured mass which deliquesces, and is soluble in alcohol. When heated, oxymuriatic acid is given out, and black oxide of iron remains still combined with muriatic acid.

Sp. 4. *Sulphated Iron.* Of this salt, likewise, there are two species, the *sulphate* and *oxysulphate.*

1. *Sulphate.* This salt was known to the ancients, and is used in considerable quantity in dyeing, and in the manufacture of ink. It is easily obtained by dissolving iron in diluted sulphuric acid and evaporating the solution. It has a green colour, sometimes very light, sometimes very dark. In this last state it is preferred by artists. Upon what the difference depends is not accurately known. It crystallizes in rhomboidal prisms. It has a very styptic taste, and always reddens vegetable blues. It is soluble in two parts of cold, and in less than its weight of boiling water. It is insoluble in alcohol. When an alkali is poured into a solu-

tion of this salt, a white powder precipitates which is a *sub sulphate of iron.* When heated it melts and loses its water of crystallization. In a red heat it loses most of its acid, and is converted into a red powder, known by the name of *colcother of vitriol,* and used in polishing metallic bodies. This salt is composed of 26·7 acid, 28·3 base, 45 water.

2. *Oxysulphate.* This salt may be formed by exposing the solution of the preceding to the open air. It has a yellowish red colour, does not crystallize and when evaporated to dryness soon attracts moisture and becomes again liquid.

Sp. 5. *Sulphite of Iron.* Iron dissolves in sulphurous acid without the emission of much gas. The solution yields crystals of sulphite, which are soon changed into sulphate by exposure to the air.

Sp. 6. *Phosphated Iron.* Of this salt there are two species, the *phosphate* and *oxyphosphate.*

1. *Phosphate.* This salt may be obtained by mixing solutions of phosphate of soda and sulphate of iron. It precipitates in the state of a blue powder. It is tasteless, insoluble in water, but soluble in nitric acid. It is found native, crystallized in blue coloured prisms.

2. *Oxyphosphate.* This is a white powder insoluble in water, but soluble in acids, and precipitated by ammonia. When violently heated it melts into an ash-coloured globule. When treated with a fixed alkali it loses a portion of its acid and is converted into a brown coloured powder. In this state it is a *suboxyphosphate of iron.* It is insoluble in water, and nearly so in acids. But it dissolves in the serum of blood, and is supposed by some to give the red colour to blood.

Sp. 7. *Carbonate of Iron.* This salt may be obtained by precipitating sulphate of iron by an alkaline carbonate. It has been found native, crystallized in rhombs, somewhat ransparent, of a greenish yellow colour, and brittle. It is omposed of 36 acid, 59·5 protoxide and two water. *Rust* s frequently a carbonateof iron. Hence it effervesces when issolved in acids.

Sp. 8. *Fluate of Iron.* Fluoric acid dissolves iron reaily. The solution does not crystallize, but assumes the form of a jelly.

Sp. 9. *Borate of Iron.* A yellow powder insoluble in water.

Sp. 10. *Acetated Iron.* Of this salt there are two species, the *acetate* and *oxacetate.*

1. *Acetate.* It may be obtained by dissolving sulphuret of iron in acetic acid. It forms green coloured prismatic crystals sufficiently soluble in water.

2. *Oxacetate.* A reddish brown liquid, which does not crystallize, but is easily converted into a jelly, which deliquesces. This liquid is much used by calico-printers.

Sp. 11. *Succinate of Iron.* A brownish red powder, insoluble in water, unless there be an excess of acid present.

Sp. 12. *Benzoate of Iron.* Yellow crystals, with a sweet taste, soluble in water and in alcohol.

Sp. 13. *Oxalated Iron.* Oxalic acid attacks iron rapidly and combines with both its oxides.

1. *Oxalate.* Prismatic crystals of a green colour, very soluble in water, with an excess of acid.

2. *Oxygenized Oxalate.* A yellow powder scarcely soluble in water, and incapable of crystallizing.

Sp. 14. *Tartrated Iron.* The *tartrate* crystallizes, and is sparingly soluble in water; the *oxytartrate* is red, does not crystallize, but runs into a jelly.

Sp. 15. *Citrate of Iron.* A brown coloured solution, which deposites small crystals very soluble in water.

Sp. 16. *Malate of Iron.* A brown solution which does not crystallize.

Sp. 17. *Gallate of Iron.* A deep blue or black powder, insoluble in water.

Sp. 18. *Prussiated Iron.* The *prussiate* is a white powder, the oxyprussiate, a deep blue powder; both insoluble in water.

Sp. 19. *Arseniated Iron.* The *arseniate* is a green coloured salt, insoluble in water, found native, crystallizes in cubes. The *oxarseniate* is a brownish red powder, likewise insoluble in water.

Sp. 20. *Tungstate of Iron.* An insoluble powder of a grey colour.

Sp. 21. *Molybdate of Iron.* An insoluble brown powder.

Sp. 22. *Columbate of Iron.* An insoluble mineral of a dark brownish grey colour, and a lamellated structure.

GENUS XI. *Salts of Tin.*

Most of these salts are soluble in water, and the solution is colourless, or has a brownish colour, according to circumstances. The prussiates, when dropt into these solutions occasion a white precipitate; hydrosulphuret of potash occasions a brownish black, or a golden yellow precipitate; corrosive sublimate occasions a black or a white precipitate; infusion of nut galls occasions no precipitate in these solutions.

Sp. 1. *Nitrated Tin.* Nitric acid acts with great violence on tin, and speedily converts it into an oxide. When the acid is much diluted, it forms a yellow coloured solution, containing *deutoxide of tin.* But when the solution is left to itself, or when it is concentrated by evaporation, the oxide of tin is precipitated. When the acid is strong, it speedily converts the metal into peroxide without dissolving any of it. During the action ammonia is formed and remains in combination with the acid.

Sp. 2. *Muriated tin.* Of this salt there are two species the *muriate* and *oxymuriate.*

1. *Muriate.* Muriatic acid dissolves tin when assisted by heat, and the salt formed is muriate of tin. By evaporation it is obtained in needle-shaped crystals, soluble in water, and somewhat deliquescent. It has a strong affinity for oxygen and readily imbibes it from the atmosphere, from oxymuriatic and nitric acids, and from various metallic oxides and salts. Hence the remarkable changes which it produces on many metallic solutions.

2. *Oxymuriate.* This salt is commonly known by the name of *smoking liquor of Libavius.* It may be formed by triturating together amalgam of tin, and corrosive sublimate, and distilling the mixture in a retort with a moderate heat. At first some water comes over, then a white smoke passes all of a sudden, which condenses into a colourless liquid, which constitutes the salt in question. If this liquid be exposed to the air, it smokes violently in consequence of its great affinity for water. When mixed with about one-third of its weight of water it crystallizes. Oxymuriate of tin may be formed also by exposing a solution of muriate of tin to the atmosphere, or by passing a current of oxymuriatic acid gas through it. When evaporated, it yields small prismatic crystals which deliquesce. When heated, it sublimes.

Sp. 3. *Sulphate of Tin.* When tin is kept in sulphuric acid, little action takes place. However, the tin is gradually oxydized, and sulphurous acid gas is emitted. The sulphate of tin, formed, may be obtained in the state of fine needles by evaporation. It may be readily obtained by pouring sulphuric acid into muriate of tin; a white powder precipitates, which is the sulphate, and which dissolves in water and crystallizes.

The *Oxysulphate of tin* does not crystallize, but assumes the form of a jelly.

Sp. 4. *Sulphite of Tin.* When tin is kept in sulphurous acid, the acid is decomposed, oxide of tin dissolved, and sulphuret of tin precipitated.

Sp. 5. *Phosphate of Tin.* A white powder insoluble in water.

Sp. 6. *Carbonate of Tin.* As far as is known, this species of salt does not exist.

Sp. 7. *Fluate of Tin.* A gelatinous solution having a very disagreeable taste.

Sp. *Borate of Tin.* A white powder insoluble in water.

Sp. 9. *Acetated Tin.* The *acetate* of tin crystallizes, the *oxacetate* forms a gummy incrystallizable mass.

Sp. 10. *Succinate of Tin.* This salt crystallizes, and is soluble in water.

Sp. 11. *Benzoate of Tin.* This salt is soluble in water, but insoluble in alcohol.

Sp. 12. *Oxalate of Tin.* Prismatic crystals, soluble in water.

Sp. 13. *Arseniate of Tin.* A white insoluble powder.

GENUS XII. *Salts of Lead.*

Many of these salts are scarcely soluble in water. Those that are, form colourless solutions, which have usually a sweet taste. The prussiates occasion a white precipitate in these solutions, hydrosulphuret of potash, a black precipitate, infusion of nutgalls, a white precipitate.

Sp. 1. *Nitrated Lead.* Of this salt there are two varieties, the first composed of yellow oxide and nitric acid, has been long known; we shall call it *oxynitrate*; the second, or *nitrate*, has been lately discovered by Proust.

1. *Oxynitrate.* This salt is easily obtained by dissolving lead in diluted nitric acid, and evaporating the solution. The crystals are sometimes tetrahedrons, having their opexes truncated; sometimes octahedrons. They are opake and white, and have a silvery lustre. Their taste is sweet and harsh. They are not altered by exposure to the air. They dissolve in less than eight parts of boiling water. When heated it decrepitates, and in a strong heat the acid is driven off, while at the same time the oxide is partially reduced to the metallic state. This salt is composed of 66 yellow oxide, 34 acid and water.

2. *Nitrate.* This salt is obtained by boiling lead in a solution of *oxynitrate.* A portion of the lead is dissolved, and the solution acquires a yellow colour. When evaporated the salt crystallizes in scales, and in small prisms. The oxide in my trials appeared to be the yellow; but Bucholz affirms that it contains less oxygen. This salt is composed of 81·5 oxide, 18·5 acid.

Sp. 2. *Hyperoxymuriate of Lead.* This salt is obtained by passing a current of oxymuriatic acid through water, in which oxide of lead is suspended. It is more soluble than muriate of lead, and is easily decomposed.

Sp. 3. *Muriate of Lead.* Muriatic acid attacks lead when assisted by heat. The muriate may be easily formed by pouring muriate of soda into a solution of nitrate of lead. The muriate precipitates in small prisms of a white colour and a satin lustre. This salt dissolves in 22 parts of cold water, and is considerably more soluble in hot water. It dissolves also in acetic acid. It is not altered by exposure to the air. When heated it melts, and when cold congeals into a semitransparent, greyish mass, formerly called *plumbum corneum.* When strongly heated it is converted into a submuriate of lead. The muriate of lead is composed of about 18¾ acid, 81¼ yellow oxide. 100 parts of the crystallized salt contain about 76 parts of metallic lead.

The *submuriate* of lead may be obtained in the state of a white powder, by treating muriate of lead with a pure alkali. When heated it assumes a fine yellowish colour. It is insoluble in water. It is employed as a paint.

Sp. 4. *Sulphate of Lead.* This salt may be obtained by pouring sulphuric acid or an alkaline sulphate into nitrate of lead. It is a white powder insoluble in water, in alcohol, and in nitric and acetic acids. It is found native, crystallized in octahedrons. It is composed of about 25 acid and 75 yellow oxide. A hundred parts of it, according to Kirwan, contain 71 of metallic lead. It may be heated to redness in a platinum crucible without alteration, but when in contact with charcoal, it melts, and the lead is reduced.

Sp. 5. *Sulphite of Lead.* This is a tasteless white powder, insoluble in water. It is composed of about 74·5 oxide, and 25·5 acid.

Sp. 6. *Phosphate of Lead.* A white tasteless powder, insoluble in water, easily obtained by pouring phosphate of soda into nitrate of lead. It is found native, usually of a green or yellow colour, and is often crystallized in six-sided prisms. It is soluble in nitric and muriatic acids, and from the last solution muriate of lead precipitates. When heated it melts, and assumes on cooling a regular polyhedral form. It is composed of 18 acid and 82 yellowish oxide.

Sp. 7. *Carbonate of Lead.* This is a white powder insoluble in water, easily obtained by mixing solutions of nitrate of lead, and an alkaline carbonate. It is found native, crystallized in six-sided prisms, and in tables. It is employed as a paint under the name of *white lead.* It is composed of 16⅓ acid, and 83⅔ yellow oxide.

Sp. 8. *Fluate of Lead.* A white powder insoluble in water, unless there be an excess of acid.

Sp. 9. *Borate of Lead.* A white insoluble powder. Before the blowpipe, it melts into a colourless glass.

Sp. 10. *Acetate of Lead.* Of this salt there are two varieties, the *superacetate* and *acetate.*

1. *Superacetate.* This salt has been long known. It is usually distinguished by the name of *sugar of lead.* It may be obtained by dissolving acetate of lead in acetic acid. It is much used by dyers and calico-printers. Its crystals are small needles, with a glossy appearance like satin. It has a sweet, and rather astringent taste. Water dissolves rather more than $\frac{1}{4}$th of its weight of this salt. It is not altered by exposure to the air. When distilled, there comes over water acidulated with acetic acid, then a yellow inflammable liquor, which has some of the properties of ether. The gasses extricated are carbonic acid in considerable quantity, with a very little heavy inflammable air. This salt is composed of 26 acid, 58 yellow oxide, 16 water.

2. *Acetate.* This salt may be obtained by boiling together in water 100 parts of sugar of lead, and 150 parts of litharge. its taste is less sweet, it is less soluble in water than the preceding variety, and it crystallizes in plates. A solution of this salt is employed by surgeons under the name of Goulard's extract.

Sp. 11. *Succinate of Lead.* Slender foliated crystals, scarcely soluble in water, but soluble in nitric acid.

Sp. 12. *Benzoate of Lead.* This salt forms white crystals soluble in water and alcohol, and decomposed by heat.

Sp. 13. *Oxalate of Lead.* Small crystals insoluble in alcohol, and scarcely soluble in water, unless there be an excess of acid present.

Sp. 14. *Tartrate of Lead.* An insoluble white powder, decomposed by a moderate heat. It is composed of 37 acid and 63 yellow oxide.

Sp. 15. *Citrate of Lead.* A white powder, difficultly soluble in water.

Sp. 16. *Malate of Lead.* A white powder, which precipitates in fine light flakes, and is insoluble in water, but easily soluble in acetic and weak nitric acid.

Sp. 17. *Arseniate of Lead.* A white powder, insoluble in water. It is composed of 35·7 acid, and 64.3 yellow oxide.

Sp. 18. *Molybdate of Lead.* A white powder, insoluble in water. It occurs native in rhomboidal plates, of a yellow colour, and is composed of 34·7 acid; and 65·3 yellow oxide.

Sp. 19. *Tungstate of Lead.* A white insoluble powder.

Sp. 20. *Chromate of Lead.* This is a fine red powder, with a shade of yellow, tasteless and insoluble water. It occurs native, crystallized in four-sided prisms, and is composed of 34·9 acid, and 65·1 oxide.

GENUS XIII. *Salts of Nickel.*

The salts belonging to this genus have been but imperfectly examined. They are generally soluble in water, and the solution has a fine green colour. Prussiate of potash dropt into them occasions a dull green precipitate, hydrosulphuret of potash a black precipitate, and the infusion of nutgalls a greyish white precipitate.

Sp. 1. *Nitrate of Nickel.* This salt crystallizes in rhomboidal prisms; has a fine green colour; when exposed to the air at first deliquesces, and afterwards falls to powder, and gradually loses the whole of its acid. It is composed of 55 acid, 25 oxide, and 20 water.

Sp. 2. *Muriate of Nickel.* This salt may be obtained by dissolving nickel in nitromuriatic acid, and evaporating the solution. It crystallizes irregularly, has an apple green colour, and deliquesces in the air. When heated it loses its water, and may be sublimed in the state of golden yellow flowers, which become green by absorbing water from the atmosphere. This salt is composed of 34 oxide, 11 acid, and 55 water.

Sp. 3. *Sulphate of Nickel.* This salt has a fine green colour, and crystallizes in six-sided prisms. It is very soluble in water, and effloresces in the air. It is composed of 35 oxide, 19 acid, and 46 water.

Sp. 4. *Carbonate of Nickel.* This salt is obtained by precipitating nitrate of nickel with carbonate of potash. It is a green powder, composed of 56·4 acid and water, 43·6 oxide.

Sp. 5. *Fluate of Nickel.* A salt which yields light-green coloured crystals.

Sp. 6. *Acetate of Nickel.* A salt which forms rhomboidal crystals of a green colour.

Sp. 7. *Oxalate of Nickel.* A green powder, scarcely soluble in water.

Sp. 8. *Arseniate of Nickel.* A soluble salt of an apple green colour.

Sp. 9. *Molybdate of Nickel.* A white insoluble matter.

GENUS XIV. *Salts of Zinc.*

Most of the salts of zinc are soluble in acids, and may be formed directly by dissolving zinc in the different acids. Their solutions are transparent and colourless. Prussiate of potash occasions a white precipitate, and infusion of nutgalls no precipitate.

Sp. 1. *Nitrate of Zinc.* Nitric scid dissolves zinc with great rapidity. The solution yields flat four-sided prisms, which deliquesce in the air. They are very soluble both in

Sp. 1. *Nitrate of Bismuth.* Nitric acid attacks bismuth with great violence. The solution is colourless, and deposits small white crystals, which are four-sided prisms. They attract a little moisture in the air. They detonate feebly on burning coals, loudly when triturated with phosphorus. When dissolved in water they are decomposed, and a white powder, which is a subnitrate of bismuth, is deposited.

Sp. 2. *Muriate of Bismuth.* This salt may be obtained by dissolving bismuth in nitromuriatic acid, and evaporating to dryness. It forms small prismatic crystals. It sublimes when heated, and forms a white mass which easily melts, formerly called *butter of bismuth.*

Sp. 3. *Sulphate of Bismuth.* This salt may be obtained by heating a mixture of bismuth and sulphuric acid. A white mass remains, decomposed by water.

Sp. 4. *Sulphite of Bismuth.* A white powder, insoluble in water.

Sp. 5. *Phosphate of Bismuth.* Crystals soluble in water, and not altered by exposure to the air. The *subphosphate of bismuth* is a white insoluble powder.

Sp. 6. *Acetate of Bismuth.* It may be obtained by mixing solutions of nitrate of bismuth and acetate of potash, and heating the mixture. Small talky crystals of acetate of bismuth gradually precipitate.

Sp. 7. *Succinate of Bismuth.* Yellow crystalline plates soluble in water.

Sp. 8. *Benzoate of Bismuth.* Needle shaped crystals, not altered by exposure to the air, soluble in water, and very sparingly soluble in alcohol.

Sp. 9. *Oxalate of Bismuth.* A white powder, scarcely soluble in water.

Sp. 10. *Tartrate of Bismuth.* A white insoluble powder.

Sp. 11. *Arseniate of Bismuth.* A white tasteless powder, sometimes having a shade of green; insoluble in water and nitric acid, but soluble in muriatic acid.

Sp. 12. *Molybdate of Bismuth.* A white insoluble powder.

GENUS XVI. *Salts of Antimony.*

The oxides of antimony combine but imperfectly with acids, and the salts which they form have not been very carefully examined. Their solutions have usually a brownish yellow colour, and in most cases a precipitate falls when they are diluted with water. Prussiate of potash and infusion of nutgalls throw down a white precipitate, hydrosulphuret of potash an orange coloured precipitate.

Sp. 1. *Nitrate of Antimony.* Nitric acid attacks antimony slowly. Nitrous gas is emitted, ammonia formed, and the metal converted into white oxide. A portion of it is dissolved, but it does not yield crystals.

Sp. 2. *Muriate of Antimony.* Muriatic acid dissolves antimony when kept long in contact with it, and deposites small needles. But it is nitro-muriatic acid that is the true solvent of antimony. The solution has a yellow colour, and contains, no doubt, *oxymuriate of antimony.* This salt was formerly known by the name of *butter of antimony.* It was prepared by triturating together one part of antimony and two parts of oxymuriate of mercury and distilling the mixture. The oxymuriate of antimony passes over in the state of a thick fatty mass of a greyish white colour, and often crystallized in four-sided prisms. It is very caustic, becomes coloured when exposed to the air, and melts at a moderate temperature.

Sp. 3. *Sulphate of Antimony.* Sulphuric acid oxidizes antimony at a boiling heat, and converts it into a white mass, from which water separates the acid.

Sp. 4. *Sulphite of Antimony.* This compound is precipitated in the state of a white powder, by pouring sulphurous acid into the solution of antimony in muriatic acid. It has an acrid and astringent taste, melts when heated and is decomposed.

Sp. 5. *Phosphate of Antimony.* This salt is soluble in water: it does not crystallize.

Sp. 6. *Acetate of Antimony.* Acetic acid dissolves the oxides of antimony, and forms a salt which crystallizes, and is soluble in water.

Sp. 7. *Oxalate of Antimony.* Small crystalline grains, scarcely soluble in water.

Sp. 8. *Tartrate of Antimony.* This salt does not crystallize, but readily assumes the form of a jelly.

Sp. 9. *Arseniate of Antimony.* A white powder insoluble in water.

Sp. 10. *Tartrate of Potash-and-Antimony.* This salt, usually called *tartar emetic,* was first made known to chemists in 1631. It may be prepared by mixing together equal parts of peroxide of antimony and tartar, and boiling them in ten times their weight of water, filtering the solution and evaporating it till a pellicle forms on the surface. It deposites regular crystals of tartar emetic. This salt is white, crystallizes in regular tetrahedrons, and gradually effloresces when exposed to the air. It dissolves in about 14¾ parts of cold water, and in about two parts of boiling water. Heat decomposes it by destroying the acid. It is composed of 35·4 tartaric acid, 39·6 peroxide of antimony, 16·7 potash and 8·3 water.

GENUS XVII. *Salts of Tellurium.*

Tellurium is too scarce a metal to expect that its salts should be completely examined. The fixed alkalies throw down, from their solutions, a white powder, which is re-dissolved by an excess of alkali. Prussiate of potash occasions no precipitate, hydrosulphuret of potash throws down a brown or blackish precipitate, and infusion of nutgalls a flaky yellow precipitate.

Sp. 1. *Nitrate of Tellurium.* Nitric acid readily dissolves tellurium. The solution is colourless, and not rendered turbid by water. When concentrated, it yields small crystals in needles.

Sp. 2. *Muriate of Tellurium.* Nitro-muriatic acid dissolves tellurium. Water throws down a white precipitate from the solution, which is re-dissolved by adding more water.

Sp. 3. *Sulphate of Tellurium.* Sulphuric acid dissolves tellurium. Water precipitates a white powder from the solution.

GENUS XVIII. *Salts of Arsenic.*

Arsenic is readily converted into an acid, and even its white oxide has acid properties. Hence it does not form permanent salts with acids. The acids however dissolve it. Prussiate of potash occasions a white precipitate in these solutions, and hydrosulphuret of potash a yellow precipitate, while the infusion of nutgalls produces no change.

Sp. 1. *Nitrate of Arsenic.* Nitric acid dissolves arsenic with violence, and separates a white powder scarcely soluble in water.

Sp. 2. *Muriate of Arsenic.* Muriatic acid dissolves arsenic when assisted by heat. It dissolves also the white oxide, especially if a little nitric acid be added. The muriate of arsenic may be obtained in small crystalline grains.

Sp. 3. *Sulphate of Arsenic.* Sulphuric acid oxidizes arsenic by the assistance of heat, the sulphate is a white powder very imperfectly soluble in water.

Sp. 4. *Acetate of Arsenic.* Acetic acid dissolves the white oxide of arsenic, and deposites crystals scarcely soluble in water.

GENUS XIX. *Salts of Cobalt.*

Most of these salts are soluble in water, and the solutions have a red colour, unless a great excess of acid be present. Alkalies precipitate a blue powder, prussiate of potash throws down a brownish yellow precipitate, hydrosulphuret of potash a black precipitate, infusion of nutgalls a yellowish white precipitate.

Sp. 1. *Nitrate of Cobalt.* Nitric acid dissolves cobalt when assisted by heat, and yields red prismatic crystals, which deliquesce in the air.

Sp. 2. *Muriate of Cobalt.* Muriatic acid dissolves cobalt when assisted by the presence of a little nitric acid. The solution is green, or, if there be no excess of acid, blue, but it becomes red when diluted with water. This solution forms the oldest and best known *sympathetic ink.* It is very much diluted with water. Characters drawn with it on paper in that state are colourless when cold, but acquires a fine green colour when heated. When the muriate is heated, it sublimes in grey coloured flowers which dissolve with great difficulty in water. The solution consists of common muriate of cobalt.

Sp. 3. *Sulphate of Cobalt.* Sulphuric acid dissolves the peroxide of cobalt with difficulty. The solution is red, and yields needle-form crystals, consisting of rhomboidal prisms, terminated by dihedral summits. It is soluble in 24 parts of cold water, insoluble in alcohol, and not altered by exposure to the air. It is composed of 26 acid, 30 oxide, 44 water.

This salt readily combines with potash and ammonia, and forms triple salts with each.

GENUS XX. *Salts of Manganese.*

These salts are mostly soluble in water. Alkalies throw down from them a red or white precipitate, which becomes black when exposed to the air. Prussiate of potash occasions a yellowish white precipitate, hydrosulphuret of potash a white precipitate, gallic acid produces no change.

Sp. 1. *Nitrate of Manganese.* Nitric acid dissolves the black oxide of manganese with the assistance of heat, provided a little sugar be added. The solution is colourless, and does not yield crystals.

Sp. 2. *Muriate of Manganese.* Muriatic acid readily dissolves black oxide of manganese when assisted by heat, abundance of oxymuriatic acid separating. The solution is colourless, and deposites small crystals of *muriate of manganese.* These crystals are not easily formed. When obtained they are hard, very soluble in water, and deliquesce in the air. Muriatic acid appears also to combine with red oxide of manganese, and to form a red solution containing oxymuriate of manganese.

Sp. 3. *Sulphated Manganese.* Sulphuric acid readily dissolves the white and red oxides of manganese. Upon the black it has no action, unless it be assisted by heat. In that case, oxygen gas is emitted in abundance, and the oxide is dissolved, being converted into red or white oxide, according to circumstances. There are two combinations of sulphuric acid and the oxides of manganese; one with the *white,* and another with the *red* oxide.

1. *Sulphate.* The solution of this salt is colourless, and yields, by evaporation, rhomboidal crystals. They have a very bitter taste, and are decomposed by heat, which drives off the acid.

2. *Oxysulphate.* The solution of this salt has a red colour. It does not readily crystallize, but when evaporated, easily passes into a jelly. When evaporated to dryness, it yields red coloured saline crusts, very soluble in water, and not altered by exposure to the air.

GENUS XXI. *Salts of Chromium.*

The salts of chromium are but very little known. For the few facts ascertained, we are indebted to Richter, Godon and Vauquelin. Prussiate of potash occasions a brown solution in these salts, infusion of nutgalls a brown precipitate, hydrosulphuret of potash a green precipitate, which a few drops of nitric acid change to yellow.

When the oxide of chromium is obtained by precipitating chromate of potash by means of a hydrosulphuret, it dissolves readily in acids. The solutions have a green colour, and the compounds are easily decomposed. Nitric acid seems to convert the oxide into chromic acid. It does not appear that these solutions are capable of affording crystals. The acids hitherto tried and found capable of dissolving oxide of chromium are the nitric, muriatic, sulphuric, phosphoric, sulphurous, and oxalic.

GENUS XXII. *Salts of Molybdenum.*

The salts belonging to this genus are as imperfect as those belonging to the preceding. None of them seem capable of crystallizing. But many acids dissolve oxide of molybdenum, and the solutions are remarkable for the changes of colour to which they are liable.

Nitric acid dissolves molybdenum with difficulty. If the quantity of metal be greater than the acid can dissolve, the solution is blue; but when a small quantity of molybdenum is dissolved in a considerable proportion of acid, the solution is yellowish brown.

Muriatic acid does not attack molybdenum, but it dissolves its oxide and forms a blue coloured solution.

Sulphuric acid dissolves molybdenum when assisted by heat, and forms a yellowish brown or a blue solution according to the proportion of metal acted on.

GENUS XXIII. *Salts of Uranium.*

Most of these salts are soluble in water, and the solution has a yellow colour. The pure alkalies occasion in these a yellow precipitate, prussiate of potash a brownish red precipitate, hydrosulphuret of potash a brownish yellow precipitate, and infusion of nutgalls a chocolate coloured precipitate.

Sp. 1. *Nitrate of Uranium.* Nitric acid readily dissolves uranium and its oxides. The solution, when sufficiently concentrated, yields crystals of nitrate either in hexagonal tables or in four-sided flat prisms, with a lemon yellow colour and greenish edges. Water dissolves more than twice its weight of this salt, and alcohol more than thrice its weight of it. These liquids, when hot, dissolve any quantity of the salt whatever. Sulphuric ether dissolves about one-fourth its weight of this salt. Nitrate of uranium deliquesces in a moist atmosphere, but when kept at the temperature of 100°, it soon falls to powder. When heated it melts, and, by continuing the heat, is decomposed. This salt is composed of 61 oxide, 25 acid and 14 water.

By exposing the nitrate to a moderate heat, it is converted into a lemon-yellow powder, insoluble in water, which is a *sub-nitrate* of uranium.

Sp. 2. *Muriate of Uranium.* Deliquescent crystals of a yellowish green colour, having the form of four-sided tables.

Sp. 3. *Sulphate of Uranium.* Sulphuric acid scarcely acts upon uranium, but it gradually dissolves its oxide, and the solution yields small crystals of a lemon-yellow colour in prisms or tables. This salt dissolves in less than its weight of cold water, and in about half its weight of boiling water. Alcohol dissolves $\frac{1}{25}$th of its weight of it. Heat decomposes it, driving off the acid and water, but a violent temperature is necessary. This salt is composed of

Acid,	18
Oxide,	70
Water,	12
	100

Sp. 4. *Acetate of Uranium.* Acetic acid dissolves oxide of uranium, and yields beautiful crystals in the form of long slender transparent four-sided prisms, terminated by four-sided pyramids.

GENUS XXIV. *Salts of Tungsten.*

This genus of salts is still unknown. None of them, from the difficulty of obtaining the metal in a state of purity, having been hitherto examined.

GENUS XXV. *Salts of Titanium.*

The salts of titanium are, in general, soluble in water, and the solution is colourless. The alkaline carbonates occasion a flaky precipitate in these solutions, prussiate of potash a yellowish brown precipitate, hydrosulphuret of potash a dirty bottle-green, and the infusion of nutgalls a very bulky blood-red precipitate. When a rod of tin is plunged into a solution of titanium, the liquid around it gradually assumes a fine red colour. A rod of zinc occasions a deep blue colour.

Sp. 1. *Nitrate of Titanium.* Nitric acid dissolves the carbonate of titanium, and yields transparent crystals in the form of elongated rhombs, having two opposite angles truncated, so as to represent six-sided tables.

Sp. 2. *Muriate of Titanium.* Muriatic acid dissolves the carbonate of titanium, and forms transparent cubic crystals. From the experiments of Vauquelin and Hecht, it appears that it is the peroxide of titanium only that combines with muriatic acid.

Sp. 3. *Sulphate of Titanium.* Sulphuric acid dissolves the carbonate of titanium. The solution does not crystallize; but yields, when evaporated, a white opake gelatinous mass.

GENUS XXVI. *Salts of Columbium.*

This genus of salts has been but imperfectly examined. Hatchett, Ekeberg and Wollaston are the only persons who have hitherto made experiments on this scarce metal. Sulphuric, nitric and muriatic acids scarcely dissolve the oxide of columbium. The oxalic, tartaric and citric acids dissolve it readily. The solutions appear to be transparent and colourless. Neither prussiate of potash nor hydrosulphuret of potash occasion any precipitate in these solutions. But infusion of nutgalls throws down an orange coloured precipitate, provided there be no excess of acid present. But a slight excess of acid prevents the precipitate from appearing.

GENUS XXVII. *Salts of Cerium.*

The salts of cerium have either a white or a yellow colour, according to the state of oxidizement of the metal. Their solutions in water have a sweet taste. Hydrosulphuret of potash throws down a white precipitate, prussiate of potash a milk-white precipitate, and infusion of nutgalls no precipitate whatever. The oxalate of ammonia occasions a white precipitate, which is insoluble in nitric and muriatic acids.

Sp. 1. *Nitrate of Cerium.* Nitric acid dissolves white oxide of cerium readily: the solution is colourless, crystallizes with difficulty, retains an excess of acid, and has an austere and sweet taste. It dissolves the red oxide with difficulty unless heat be applied. The solution is yellow, and yields small white crystals, which deliquesce when exposed to the air. Both of these salts are soluble in alcohol. Heat decomposes them, leaving a red coloured oxide.

Sp. 2. *Muriate of Cerium.* Muriatic acid dissolves red oxide of cerium when assisted by heat, oxymuriatic gas is exhaled, and the solution has a yellowish red colour, which becomes lighter the longer the heat is continued. The solution yields four-sided prismatic crystals of a yellowish white colour. They are soluble in alcohol, and deliquesce when exposed to the air. Their taste is astringent and sweet. Heat decomposes this salt by driving off the acid and water.

Sp. 3. *Sulphate of Cerium.* Sulphuric acid dissolves the red oxide of cerium by long digestion, an orange coloured solution is obtained, which yields small octahedral and needle-form crystals. The colour of these crystals is partly lemon yellow, partly orange. They are scarcely soluble in water. Their taste is acid and sweet. When exposed to the air they soon fall into a yellow powder.

Sulphuric acid dissolves the white oxide of cerium very readily. The solution is colourless, has a sweet taste, and yields crystals of sulphate of cerium.

Sp. 4. *Carbonate of Cerium.* When white oxide of cerium is precipitated from its solutions by an alkaline carbonate, carbonate of cerium is obtained. It is a granular powder of a silvery whiteness, insoluble in water, and composed of 23 acid, 65 oxide, and 12 water.

Sp. 5. *Acetate of Cerium.* Acetic acid dissolves the white oxide of cerium, and forms small sweet-tasted crystals soluble in water, but very sparingly soluble in alcohol.

CHAPTER IV.

OF HYDROSULPHURETS.

Sulphureted hydrogen gas possesses many of the properties of an acid, and, like acids, it combines with the salifiable bases, and forms a class of bodies called *hydrosulphurets.* These bodies are of considerable importance, as they are frequently employed in chemical analysis, and enable us to separate the metallic oxides from alkalies and earths, because they throw down almost the whole of them from their solutions in an insoluble state.

The hydrosulphurets are soluble in water, and the solution is colourless. When the solution is exposed to the air it becomes green or greenish yellow. After long exposure to the air, the solution becomes again limpid and colourless, and on examination is found only to contain the base of hydrosulphuret combined with sulphuric acid. The solution of the hydrosulphurets precipitate almost all the metallic oxides from their solutions; iron and lead black, antimony orange, arsenic yellow, &c.

The hydrosulphurets may be formed by dissolving or diffusing the respective bases in water, and passing a current of sulphureted hydrogen gas through the liquid till it ceases to absorb any more. The excess of gas is then driven off by heat; and the hydrosulphuret may be obtained in a solid state if required by evaporation. The yellow colour which these solutions acquire when exposed to the air, is owing to the decomposition of the sulphureted hydrogen by the gradual absorption of oxygen from the atmosphere.

Sp. 1. *Hydrosulphuret of Barytes.* When sulphate of barytes is converted into sulphuret by mixing it with charcoal, and heating it red hot in a crucible, if boiling water be poured upon the black mass, and filtered while hot, the green coloured solution thus obtained yields by evaporation a great number of crystals. These crystals are hydrosulphuret of barytes. They are white, and have a silky lustre. They have the form of scales, and the shape cannot easily be distinguished. This substance is soluble in water, the solution has a slight tint of green, its taste is acrid and sulphureous, and when exposed to the air, is readily decomposed.

Sp. 2. *Hydrosulphuret of Strontian.* It may be procured by the same process as the preceding hydrosulphuret, and its properties are nearly similar.

Sp. 3. *Hydrosulphuret of Potash.* This substance is formed during the solution of sulphuret of potash, and may be obtained by evaporation. It is transparent and colourless, and crystallizes in large prisms, not unlike the figure of sulphate of soda. Its taste is alkaline, and extremely bitter. When exposed to the air it soon deliquesces into a liquor of a syrupy consistence, tinging green all bodies with which it happens to come in contact. The crystals have no smell at first, but when they have deliquesced, they emit a fetid odour. They dissolve both in water and alcohol, and during the evolution, the temperature sinks considerably. Acids drive off the sulphureted hydrogen with a violent effervescence.

Sp. 4. *Hydrosulphuret of Soda.* The crystals of this substance are transparent and colourless, having the figure of four terminated by quadrangular pyramids. Its
d intensely bitter. It is very soluble both
hol, and during the solution cold is pro-

duced. When exposed to the air it deliquesces, and acquires a green colour. Acids drive off the sulphureted hydrogen.

Sp. 5. *Hydrosulphuret of Lime.* This substance may be formed by passing sulphureted hydrogen gas through water, having lime suspended in it. The solution is colourless, and has an acrid and bitter taste.

Sp. 6. *Hydrosulphuret of Ammonia.* This compound may be formed by passing sulphureted hydrogen through liquid ammonia. When equal parts of lime, sal ammoniac and sulphur mixed with a little water are distilled in a retort, a yellow liquid is obtained, usually distinguished by the name of *fuming liquor of Boyle,* because first prepared by that philosopher. This liquid is little else than hydrosulphuret of ammonia holding an excess of ammonia in solution.

Sp. 7. *Hydrosulphuret of Magnesia.* This substance may be formed by passing a current of sulphureted hydrogen through water in which magnesia is diffused. Its properties have not been hitherto examined.

Sp. 8 and 9. *Hydrosulphurets of Glucina* and *of Yttria.* From the experiments of Klaproth and Vauquelin, we know that the hydrosulphurets do not precipitate glucina or yttria from acids. Hence it is likely that they are capable of combining with sulphureted hydrogen, though these combinations have not hitherto been examined by chemists.

Neither alumina nor zirconia combine with sulphureted hydrogen. Hence the hydrosulphurets precipitate these earths from acids.

When the alkalies and alkaline earths are mixed with sulphur and water, and boiled in a glass vessel, a brown coloured solution is obtained, formerly called *liquid liver of sulphur.* At present the term *hydrogureted sulphurets* is applied to these solutions. They are conceived to be combinations of the alkaline bases with sulphur and sulphureted hydrogen at potash a milk-white precipitate, and infusion of nutgalls no precipitate whatever. The oxalate of ammonia occasions a white precipitate, which is insoluble in nitric and muriatic acids.

Sp. 1. *Nitrate of Cerium*. Nitric acid dissolves white oxide of cerium readily: the solution is colourless, crystallizes with difficulty, retains an excess of acid, and has an austere and sweet taste. It dissolves the red oxide with difficulty unless heat be applied. The solution is yellow, and yields small white crystals, which deliquesce when exposed to the air. Both of these salts are soluble in alcohol. Heat decomposes them, leaving a red coloured oxide.

Sp. 2. *Muriate of Cerium*. Muriatic acid dissolves red oxide of cerium when assisted by heat, oxymuriatic gas is exhaled, and the solution has a yellowish red colour, which becomes lighter the longer the heat is continued. The solution yields four-sided prismatic crystals of a yellowish white colour. They are soluble in alcohol, and deliquesce when exposed to the air. Their taste is astringent and sweet. Heat decomposes this salt by driving off the acid and water.

Sp. 3. *Sulphate of Cerium*. Sulphuric acid dissolves the red oxide of cerium by long digestion, an orange coloured solution is obtained, which yields small octahedral and needleform crystals. The colour of these crystals is partly lemon yellow, partly orange. They are scarcely soluble in water. Their taste is acid and sweet. When exposed to the air they soon fall into a yellow powder.

Sulphuric acid dissolves the white oxide of cerium very readily. The solution is colourless, has a sweet taste, and yields crystals of sulphate of cerium.

Sp. 4. *Carbonate of Cerium*. When white oxide of cerium is precipitated from its solutions by an alkaline carbonate, carbonate of cerium is obtained. It is a granular powder of a silvery whiteness, insoluble in water, and composed of 23 acid, 65 oxide, and 12 water.

Sp. 5. *Acetate of Cerium.* Acetic acid dissolves the white oxide of cerium, and forms small sweet-tasted crystals soluble in water, but very sparingly soluble in alcohol.

CHAPTER IV.

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The hydrosulphurets are soluble in water, and the solution is colourless. When the solution is exposed to the air it becomes green or greenish yellow. After long exposure to the air, the solution becomes again limpid and colourless, and on examination is found only to contain the base of hydrosulphuret combined with sulphuric acid. The solution of the hydrosulphurets precipitate almost all the metallic oxides from their solutions; iron and lead black, antimony orange, arsenic yellow, &c.

The hydrosulphurets may be formed by dissolving or diffusing the respective bases in water, and passing a current of sulphureted hydrogen gas through the liquid till it ceases to absorb any more. The excess of gas is then driven off by heat; and the hydrosulphuret may be obtained in a solid state if required by evaporation. The yellow colour which

2. *Oxysulphate.* The solution of this salt has a red colour. It does not readily crystallize, but when evaporated, easily passes into a jelly. When evaporated to dryness, it yields red coloured saline crusts, very soluble in water, and not altered by exposure to the air.

GENUS XXI. *Salts of Chromium.*

The salts of chromium are but very little known. For the few facts ascertained, we are indebted to Richter, Godon and Vauquelin. Prussiate of potash occasions a brown solution in these salts, infusion of nutgalls a brown precipitate, hydrosulphuret of potash a green precipitate, which a few drops of nitric acid change to yellow.

When the oxide of chromium is obtained by precipitating chromate of potash by means of a hydrosulphuret, it dissolves readily in acids. The solutions have a green colour, and the compounds are easily decomposed. Nitric acid seems to convert the oxide into chromic acid. It does not appear that these solutions are capable of affording crystals. The acids hitherto tried and found capable of dissolving oxide of chromium are the nitric, muriatic, sulphuric, phosphoric, sulphurous, and oxalic.

GENUS XXII. *Salts of Molybdenum.*

The salts belonging to this genus are as imperfect as those belonging to the preceding. None of them seem capable of crystallizing. But many acids dissolve oxide of molybdenum, and the solutions are remarkable for the changes of colour to which they are liable.

Nitric acid dissolves molybdenum with difficulty. If the quantity of metal be greater than the acid can dissolve, the solution is blue; but when a small quantity of molybdenum is dissolved in a considerable proportion of acid, the solution is yellowish brown.

Muriatic acid does not attack molybdenum, but it dissolves its oxide and forms a blue coloured solution.

Sulphuric acid dissolves molybdenum when assisted by heat, and forms a yellowish brown or a blue solution according to the proportion of metal acted on.

GENUS XXIII. *Salts of Uranium.*

Most of these salts are soluble in water, and the solution has a yellow colour. The pure alkalies occasion in these a yellow precipitate, prussiate of potash a brownish red precipitate, hydrosulphuret of potash a brownish yellow precipitate, and infusion of nutgalls a chocolate coloured precipitate.

Sp. 1. *Nitrate of Uranium.* Nitric acid readily dissolves uranium and its oxides. The solution, when sufficiently concentrated, yields crystals of nitrate either in hexagonal tables or in four-sided flat prisms, with a lemon yellow colour and greenish edges. Water dissolves more than twice its weight of this salt, and alcohol more than thrice its weight of it. These liquids, when hot, dissolve any quantity of the salt whatever. Sulphuric ether dissolves about one-fourth its weight of this salt. Nitrate of uranium deliquesces in a moist atmosphere, but when kept at the temperature of 100°, it soon falls to powder. When heated it melts, and, by continuing the heat, is decomposed. This salt is composed of 61 oxide, 25 acid and 14 water.

By exposing the nitrate to a moderate heat, it is converted into a lemon-yellow powder, insoluble in water, which is a *sub-nitrate* of uranium.

Sp. 2. *Muriate of Uranium.* Deliquescent crystals of a yellowish green colour, having the form of four-sided tables.

swers better than any other hitherto tried. These plasters soften when heated, and adhere very strongly to the skin when spread thin upon linen or leather, but they may be drawn off, by using the requisite force, without leaving any portion adhering to the skin. In these properties their excellence consists.

DIVISION IV.

OF VEGETABLE SUBSTANCES.

The substances hitherto found in the vegetable kingdom, all of them at least which have been examined with any degree of accuracy, may be reduced under four heads: I. Substances soluble in water, at least in some state or other, and which, in general, are solid and not remarkably combustible. II. Substances, either fluid, or which melt when heated, and burn like oil. They are all insoluble in water; but, in general, they dissolve in alcohol. III. Substances neither soluble in water nor alcohol nor ether, and which have a fibrous or woody texture. IV. Substances which belong to the mineral kingdom, which occur only in small quantity in vegetables, and may therefore be considered as extraneous or foreign. The following table exhibits a view of the different vegetable substances hitherto discovered, arranged under their respective heads.

I. 1 Acids.
2 Sugar.
3 Sarcocoll.
4 Asparagin.
5 Gum.
6 Mucus.
7 Jelly.
8 Ulmin.
9 Inulin.
10 Starch.
11 Indigo.
12 Gluten.
13 Albumen.
14 Fibrin.
15 Bitter principle.
16 Extractive.
17 Tannin.
18 Narcotic principle.

II. *Oleoform.*

1 Fixed oil.
2 Wax.
3 Volatile oil.
4 Camphor.
5 Bird-lime.
6 Resins.
7 Guaiacum.
8 Balsams.
9 Gum resins.
10 Caoutchouc.

III. *Fibrous.*

1 Cotton.
2 Suber.
3 Wood.

IV. *Extraneous.*

1 Alkalies.
2 Earths.
3 Metals.

The properties of these different substances form the subject of the following chapters.

CHAP. I.

OF ACIDS.

The acids found ready formed in the vegetable kingdom, are the following:

1 Acetic.
2 Oxalic.
3 Tartaric.
4 Citric.
5 Malic.
6 Gallic.
7 Benzoic.
8 Prussic.
9 Phosphoric.

The sulphuric, nitric and muriatic acids are likewise to be found in vegetables combined with alkalies, but only in small quantities.

1. Acetic acid has been detected in the sap of different trees, in the acid juice of the *cicer parietinum*, and in the *sambucus nigra*.

2. Oxalic acid in the state of *superoxalate of potash* exists in the leaves of the *oxalis acetosella, oxalis corniculata*, and different species of *rumex*. It exists uncombined in the juice of the *cicer parietinum*. In the state of *oxalate of lime* it is found in *rhubarb*, and in the roots and barks of a great variety of plants.

3. Tartaric acid is found in the pulp of the *tamarind*, in the juice of *grapes* and *mulberries*; likewise in the *rumex acetosa, rhus coriaria, rheum rhaponticum, agave americana, triticum repens, leontodon taraxacum*. In most of these plants it is in the state of supertartrate of potash.

4. Citric acid is found intermixed with other acids in the juice of *oranges* and *lemons*, and in the berries of *vaccinium oxycoccos, vaccinium vitis idæa, prunus padus, solanum dul-*

amara, rosa canina. Mixed with other acids it is common in many fruits. *Citrate of lime* is found in the onion.

5. Malic acid is very common in plants. It was found by Scheele, unmixed with any other acid, in the fruits of the following plants; the *apple, berberis vulgaris, prunus domestica, prunus spinosa, sambucus nigra, sorbus aucuparia.* Braconnot has found it in the leaves of most vegetables which he examined. Vauquelin found it in the state of *supermalate of lime* in the following plants; *sempervivum tectorum, sedum album, sedum acre, sedum telephium, arum maculatum,* and different species of *crassula* and *mesembrianthemum.* Mixed with citric acid, it constitutes the acid of the following fruits; *gooseberries, currants, bleaberries, cherries, strawberries, cloudberries, raspberries.* Sometimes, as in the tamarind, it is mixed with tartaric acid.

6. Gallic acid has been found in the bark of most astringent tasted trees; as, elm, oak, horse-chesnut, beech, willow, elder, plum, sycamore, birch, cherry-tree, mountain-ash, poplar, hazel, ash, sumach.

7. Benzoic acid has been found only in a few vegetable substances, to which the name of *balsam* has been given. The chief of these are *benzoin, balsam of tolu, storax, dragon's blood.*

8. Prussic acid has been found in the leaves of the *lauro-cerasus,* in *peach blossoms,* in the flowers of the *sloe,* in the leaves of the bay-leaved *willow* (*salix pentandra*), and in most bitter tasted kernels.

9. Phosphoric acid is very common in plants, but only in small quantities, and it is usually combined with potash or lime. Phosphate of potash exists in barley and other species of corn, so does phosphate of lime. Both of these salts exist in the leaves of many trees.

CHAP. II.

OF SUGAR.

Common sugar is obtained from the juice of the *arundo sacharifera* or *sugar cane,* a plant cultivated from time immemorial in India and China. It was unknown in Europe till after the conquests of Alexander the Great. The cultivation of the sugar cane was gradually introduced into Sicily and Spain, and, after the discovery of America, it was imported to the West Indian islands, where it has been cultivated to a great extent. Sugar has, in consequence, become a necessary of life among the modern nations of Europe.

The juice is extracted by passing the cane between iron rollers, and immediately run into a flat copper cauldron, where it is mixed with a little lime and heated to the temperature of 140°. A thick viscid scum collects on the surface, which is left unbroken, and the clear liquid drawn from below and introduced into a large boiler. Here it is boiled briskly, the scum, as it forms, being constantly removed. From this first boiler it is passed into a second, from that to a third and fourth, in each of which the boiling is continued. When sufficiently concentrated, it is poured into a large wooden vessel called the *cooler,* where it crystallizes or *grains* as it cools. From the cooler it is taken and put into hogsheads, having a hole in the bottom, into which the stalk of a plantain leaf is thrust. Through these holes the *molasses* drain into a receiver. The sugar, thus cleared, is brought to this country under the name of *raw sugar.* It is refined by solution in water, clarified by bullock's blood, boiled down and poured into earthen cones, having a hole in the apex which is undermost. The base of the cone is covered with moist clay. From this the water slowly penetrates through the sugar, and carries off the impurities. In this state it is white, and is known by the name of *loaf sugar.*

From the experiments of Proust, it appears that sugar cane juice contains gluten, gum, extractive, a little malic acid, sulphate of lime, aud two species of sugar. The object of the process is to remove all the substances except the crystallizable sugar.

Sugar is a firm white substance of an extremely sweet taste, but destitute of smell. It is but little altered by exposure to the atmosphere, though in damp air it is liable to become moist.

Cold water dissolves nearly its own weight of sugar, and boiling water dissolves any quantity whatever. The solution constitutes a thick, ropy, adhesive fluid called syrup. When syrup is sufficiently concentrated, and kept in open vessels in a hot place, the sugar gradually crystallizes. The crystals are four or six-sided prisms, terminated by two-sided, and sometimes by three-sided summits.

The specific gravity of white sugar is 1·6065. It is not acted on by oxygen gas, by the simple combustibles, by azote or by the metals. The alkaline earths combine with sugar and form a compound which has a bitter and astringent taste. Sugar facilitates the solubility of lime and strontian in water; but bărytes appears to act with more energy, and to occasion decomposition of sugar. The fixed alkalies combine with sugar, and form compounds similar to those formed by the alkaline earths.

The acids dissolve sugar, and the more powerful mineral acids decompose it. Nitric acid dissolves it with effervescence, converts one-half of its carbon into carbonic acid, the residue assumes the form of water and oxalic acid. A quantity of malic acid is also evolved. 100 grains of sugar yield, by this treatment, 58 grains of oxalic acid. Oxymuriatic acid, according to Chenevix, converts sugar into citric acid. Sulphuric acid decomposes sugar, water and acetic acid are formed, and a great quantity of charcoal evolved.

Sugar dissolves in about 16 parts of boiling alcohol. If the solution be set aside, the sugar is gradually deposited in elegant crystals.

The hydrosulphurets, sulphurets and phosphurets of alkalies and earths seem to have the property of decomposing sugar, and of bringing it to a state not very different from that of gum.

When heat is applied to sugar, it melts, swells, becomes brownish black, emits air bubbles, and emits the smell of caromel. At a red heat it bursts into flames with a kind of explosion. When distilled, there comes over water; an acid liquid called *pyromucous acid*, now known to be the acetic mixed with a little empyreumatic oil; an oil; and a bulky charcoal remains in the retort. During the distillation a considerable quantity of carbonic acid and heavy inflammable air come over.

From the experiments of Lavoisier, compared with some of my own, it appears that sugar is composed of

64	oxygen
28	carbon
8	hydroge
100	

It appears from the recent researches of chemists, that there exist various species of sugar differing from each other in their properties. The most important of these are the following: common sugar, liquid sugar, sugar of grapes, sugar of beet, manna.

Common sugar is the substance described in the preceding part of this chapter. It is obtained from the sugar cane. The properties of the sugar of the maple are not known to differ from those of common sugar.

Liquid sugar was first pointed out by Proust. It exists in a variety of fruits and vegetable juices. It does not crystallize, and can only be exhibited in a liquid state. It is more soluble in alcohol than common sugar. It exists in the juice of the sugar-cane, and constitutes no inconsiderable portion of *molasses.*

Sugar was first extracted from grapes by the Duc de Bullion. They often yield, according to Proust, from 30 to 40 per cent. of sugar. He extracted it by saturating the acids contained in the juice of grapes with potash, boiling it down to one half, and setting it aside. Several of the salts subsided. The juice was then mixed with blood, heated, scummed, filtered, and boiled down to a syrup. Crystals of raw sugar gradually form which may be purified by repeating the process. This sugar is white, but inferior in consistence to common sugar. It is not so sweet, and resembles sugar from honey. Like it, the sugar of grapes crystallizes in sphericles. It is less soluble than common sugar, and does not go so far in sweetening liquids.

Sugar was first extracted from the beet by Margraff. Many experiments were afterwards made upon the extraction by Achard and other German philosophers, and attempts made to substitute the sugar of beet for common sugar, but it could not be obtained at a low enough price. It has a greater resemblance to common sugar than the sugar of grapes; but is distinguished by a certain nauseous bitter taste, owing perhaps to the presence of some foreign substance.

Manna is the produce of various trees, but is chiefly obtained from the *fraxinus ornus,* a species of *ash,* which grows abundantly in Sicily and Calabria. It partly exudes spontaneously during the summer months, and is partly obtained by incisions. The juice gradually concretes into a solid mass, or it is dried in the sun or in stoves. Pure manna is very light, and appears to consist of a congeries of fine capillary crystals. Its taste is sweet, and it leaves a nauseous impression in the mouth. Hot alcohol dissolves it readily, and, on cooling, deposites about 5-8ths of the manna in the state of a fine light spongy crystalline mass, bearing some resemblance to camphor. This deposite may be considered as pure manna. It has an agreeable sweet taste, and instantly melts on the tongue like snow in warm water. When dissolved in nitric acid, it yields oxalic acid. The saclactic appears also when the manna is impure. Manna does not undergo the vinous fermentation, and seems in consequence incapable of furnishing alcohol. Manna itself seems to be formed from uncrystallizable sugar by a species of fermentation.

The plants yielding sugar are very numerous. It seldom exudes spontaneously from vegetables, though this is sometimes the case.

CHAP. III.

OF SARCOCOLL.

This substance, which has hitherto been confounded with the gum resins, though its properties are very different, exudes spontaneously from the *penæa sarcocolla*, a shrub said by botanical writers to be indigenous in the north-eastern parts of Africa. It may be obtained pure by solution in alcohol, filtration and evaporation.

Pure sarcocoll has a brown colour, is semitransparent, and very like gum in appearance. Its specific gravity is 1·2684.

It has a sweet taste, but leaves an impression of bitterness. It dissolves readily both in water and alcohol. The solution is yellow. It does not crystallize. When heated, it softens, but does not melt. It emits a slight smell of caromel.

When strongly heated it blackens, and assumes the consistence of tar, emitting a heavy white smoke, having an acrid odour. Nitric acid dissolves it, but does not convert it into tannin. From these properties sarcocoll appears to be intermediate between gum and sugar.

CHAP. IV.

OF ASPARAGIN.

I GIVE this name to a substance discovered in the juice of *asparagus* by Vauquelin and Robiquet. The juice was evaporated to the consistence of a syrup, and set aside. Crystals of asparagin formed in it spontaneously.

These crystals are white and transparent, and have the figure of rhomboidal prisms. The greater angle of the rhomboidal base is 130°.

Asparagin is hard and brittle. Its taste is cool, and slightly nauseous, so as to occasion a secretion of saliva.

It dissolves readily in hot water, but in cold water only sparingly. Alcohol does not dissolve it.

The aqueous solution does not affect vegetable blues. Neither infusion of nutgalls, acetate of lead, oxalate of ammonia, muriate of barytes, nor hydrosulphuret of potash occasion any change in it. When triturated with potash no ammonia is disengaged. The potash seems to render it more soluble in water.

When heated it swells, and emits penetrating vapours, affecting the eyes and nose like the smoke of wood. It leaves a large portion of insipid charcoal, which, when incinerated, gives scarcely a trace of residue.

Nitric acid dissolves it with the evolution of nitrous gas. The solution has a yellow colour, and a bitter taste like that of animal substances in the same acid. Lime disengages from it a considerable quantity of ammonia.

CHAP. V.

OF GUM.

THERE is a thick transparent tasteless fluid, which sometimes exudes from certain species of trees. It is very adhesive, and gradually hardens without losing its transparency, but easily softens again when moistened with water. This exudation is known by the name of gum. The gum most commonly used is that which exudes from different species of the *mimosa*, particularly the *nilotica*, and is known by the name of *gum arabic*.

Gum is usually obtained in small pieces like tears, moderately hard, and somewhat brittle while cold, so that it can be reduced by pounding to a fine powder. When pure it is colourless; but it has commonly a yellowish tinge, and it is not destitute of lustre. It has no smell. Its taste is insipid. Its specific gravity varies from 1·3161 to 1·4817.

It is not altered by exposure to the air, but the light of the sun makes it assume a white colour. Water dissolves it in large quantities. The solution, which is known by the name of *mucilage*, is thick and adhesive. It is often used as a paste, and to give stiffness and lustre to linen. When evaporated, the gum is obtained unaltered. Mucilage may be kept for years without undergoing putrefaction: at last, however, the odour of acetic acid becomes perceptible in it.

When gum is exposed to heat it softens and swells, but does not melt; it emits air bubbles, blackens, and at last when nearly reduced to charcoal, emits a low blue flame.

A white ash remains, consisting chiefly of the carbonates of lime and potash.

Gum does not appear to be acted on by oxygen gas, the simple combustibles, azote or the metals. The only metallic salts which occasion a precipitate when dropt into mucilage, are *nitrate of mercury*, and *acetate of lead*, both of which occasion a white precipitate. The superacetate of lead occasions no change. When oxymuriate of iron is poured into a strong mucilage, the whole is converted into a brown semitransparent jelly, which is not readily dissolved by water.

Neither the alkalies, alkaline earths, nor earthy salts occasion any precipitate in mucilage; except silicated potash, which throws down a white flaky precipitate, even though very much diluted. The liquid remains transparent and colourless. Silicated potash is by far the most delicate test of gum that I have yet met with.

Liquid potash first converts gum into a substance not unlike curd, and then dissolves it. The solution is of a light amber colour, and transparent. When kept long, the gum falls again in the state of curd. Alcohol throws down the gum in white flakes, still soluble in water, but it retains the potash obstinately, and is much more friable than before. Lime water and ammonia likewise dissolve gum, and it may be afterwards separated little altered.

The vegetable acids dissolve gum without alteration, the strong acids decompose it. When thrown into sulphuric acid it blackens, and is decomposed. Charcoal is evolved, amounting to nearly one-third of the gum; some artificial tannin may be detected, and water and acetic acid are likewise formed. When gum is dissolved in strong muriatic acid, a brown solution is obtained, which becomes perfectly transparent when diluted with water, while at the same time some charry matter falls. If the solution be saturated with ammonia evaporated to dryness, and the residue digested in alcohol, the alcohol assumes a deep brown colour, and dissolves the whole except a little sal ammoniac. The gum now bears some resemblance to sugar in its properties, at least when heated it melts, and gives out a very strong smell of caromel.

Oxymuriatic acid, according to Vauquelin, converts gum into citric acid. If nitric acid be slightly heated upon gum till it has dissolved it, and till a little nitrous gas has exhaled, the solution on cooling deposites saclactic acid. Malic acid is formed at the same time, and if the heat be continued, the gum is at last changed into oxalic acid.

Gum is insoluble in alcohol. It is precipitated from water by alcohol. It is insoluble also in ether and in oils; but when triturated with a little oil, it renders the oil miscible with water.

Gum readily combines with sugar by mixing together the solutions of both in water, and evaporating to dryness. Alcohol digested on the residuum, dissolves most of the sugar, a matter remains which still has a sweetish taste and resembles the substance of which the nests of wasps are formed.

When gum is distilled in a retort, the products are water impregnated with acetic acid and oil, or *pyromucous acid*, as it was formerly called, a little empyreumatic oil, carbonic acid gas, and heavy inflammable air. There remains in the retort charcoal containing lime and phosphate of lime. Gum yields also traces of iron when its ashes are examined, but no fixed alkali or sulphur can be detected.

The species of gum at present known are numerous, and a more rigid examination of the vegetable kingdom will doubtless discover a still greater number. The most remarkable are gum arabic, gum senegal, gum tragacanth, and cherry tree gums.

Gum arabic exudes from the *mimosa nilotica*. It is the species described in the preceding part of this chapter.

Gum senegal, brought from the island of that name on the coast of Africa, often supplies the place of gum arabic in the shops. It is in larger masses than the arabic, and its colour is darker, but in other respects its properties are the same.

Gum tragacanth is the produce of the *astragalus tragacantha*, a thorny shrub which grows in Candia, and other islands of the Levant. It exudes about the end of June, from the stem and larger branches, and soon dries in the sun. It is in the state of whitish vermiform pieces, not nearly so transparent as gum arabic, and is exceedingly different from it in many of its properties. When put into water, it slowly imbibes a large quantity of the liquid, and forms a soft but not fluid mucilage. If the quantity of water be more than the gum can imbibe, the mucilage forms an irregular mass, which does not unite with the rest of the liquid. When tragacanth is treated with nitric acid, it yields abundance of saclactic acid, malic acid, and oxalic acid, but not the least trace of artificial tannin. When the mucilage of gum tragacanth is triturated in a mortar with water, it forms a homogeneous solution. This solution forms a precipitate with acetate and superacetate of lead and oxymuriate of tin. Nitrate of mercury throws down a slight precipitate; but neither oxysulphate of iron, nor silicated potash produce any effect. These properties show it to differ very materially from gum arabic in its properties.

The *prunus avium*, the common cherry and plum-trees, and the almond and apricot likewise yield a gum which exudes in great abundance from natural or artificial openings in the stem. It is of a reddish brown colour, in large masses, at first much softer than gum arabic, but, by keeping, it becomes very hard. When put into water it gradually swells, and is converted into a semi-transparent reddish brown jelly.

Part of it dissolves, but a part of it remains in the state of jelly, and refuses to dissolve even when boiled in water for some time. The gum dissolved is not precipitated by alcohol nor by silicated potash. Acetate of lead produces no immediate effect, but on standing the whole becomes opake, and a precipitate at last subsides. Oxymuriate of tin causes the liquid to gelatinize immediately. The superacetate of lead and the nitrate of mercury produce no effect. When treated with nitric acid, it yields a portion of saclactic acid. These properties show a marked difference between cherry-tree gum and the other species.

CHAP. VI.

OF MUCUS.

The substances to which I give the name of *mucus*, have been hitherto considered as varieties of gum; but, from the recent experiments of Dr Bostock, it appears that their properties differ so much from those of gum as to entitle them to a separate place as vegetable principles. They are very numerous, existing in the roots, leaves and seeds of a great variety of plants. They scarcely ever separate spontaneously, but may be obtained artificially in a state of tolerable purity. Only a few of them have been examined. The rest are classed with these only from analogy.

Linseed yields mucus in a state of tolerable purity. When it is infused in ten times its weight of water, a fluid is obtained of the consistence of white of egg, which has the adhesive qualities of mucilage of gum arabic. When mixed with alcohol, the mucus is separated in white flocks, but the liquid does not become opake and milky like mucilage of gum arabic when mixed with alcohol. Acetate of lead throws down a copious dense precipitate. Superacetate of lead and oxymuriate of tin render the liquid opake, and also throw down a precipitate. Nitrate of mercury occasions a very slight precipitate, while muriate of gold, oxysulphate of iron and silicated potash produce no sensible effect whatever. No change is produced by the infusion of nutgalls.

Quince seeds and the root of the hyacinth yield a mucus with the same properties with some slight shades of difference, owing probably to the presence of foreign bodies mixed with it. The roots of the hyacinth, vernal squill, white lilly, comfrey and salop, contain so much mucus that, when dried, they may be substituted for gum arabic. The leaves of the *malva sylvestris*, many of the fuci, and a good many of the stringy lichens, contain likewise abundance of mucus. In short, it is one of the most common of the vegetable principles. Probably there are few plants which do not yield some portion of it.

CHAP. VII.

OF JELLY.

If we press out the juice of blackberries, currants and many other fruits, and allow it to remain for some time in a state of rest, it coagulates into a tremulous soft substance, well known by the name of *jelly*. When it is washed with a small quantity of water and then dried, we obtain it in a state approaching to purity.

It is nearly colourless, scarcely soluble in cold water, but very soluble in hot water, and, when the solution cools, it again coagulates into a jelly. When long boiled, it loses the property of gelatinizing, and becomes analogous to mucilage. When dried it becomes transparent. When distilled it yields the same products as gum. It seems very intimately connected with gum; but, as it has never been obtained in a state of complete purity, we are but imperfectly acquainted with its properties.

CHAP. VIII.

OF ULMIN.

I give this name to a singular substance lately examined by Klaproth. It exuded spontaneously from the trunk of a species of elm, supposed to be the *ulmus nigra*, and was sent to Klaproth from Palermo in 1802.

Externally it has a good deal of resemblance to gum. It is solid, hard, of a black colour, and has considerable lustre. Its powder is brown. It dissolves readily in the mouth, and has an insipid taste.

Water dissolves it. The solution has a brown colour. Though very strong, it is not in the least adhesive or ropy, nor does it answer as a paste. It is insoluble in alcohol and ether, and is partially precipitated from water by alcohol.

When a few drops of nitric acid are added to the aqueous solution of ulmin, it becomes gelatinous, loses its brown colour and a light brown substance precipitates. This precipitate is soluble in alcohol, and possesses the properties of a resin. Oxymuriatic acid produces nearly the same effect. Thus it appears that ulmin, by the addition of a little oxygen, is converted into a resinous substance. This property is very singular. Hitherto the volatile oils were the only substances known to assume the form of resins. That a substance soluble in water should assume the resinous form with such facility is very remarkable.

Ulmin when burnt emits little smoke or flame, it leaves a spongy but firm charcoal, which yields, when concentrated, a little carbonate of potash.

CHAP. IX.

OF INULIN.

I give this name to a substance discovered by Rose in the root of the *inula helenium* or *elecampane*. When the root of this vegetable was boiled in water, the decoction, after standing some hours, deposites the *inulin* in the form of a white powder like starch.

It is insoluble in cold water. By trituration the inulin is uniformly diffused, and gives the liquid an opal appearance, but it soon falls down in the state of a white powder, leaving the liquid quite transparent.

It dissolves readily in hot water. One part of inulin in four parts of boiling water formed a solution which passed readily through the filter. After some hours the greater part of the inulin precipitates from the water in the form of a white powder.

When the aqueous solution of inulin is mixed with an equal bulk of alcohol, no change takes place for some time; but the inulin soon separates and falls to the bottom in the state of a bulky white powder. A solution of gum arabic, when treated in this manner, remains milky for days without any precipitate falling.

When thrown upon burning coals it melts as readily as sugar, and emits a thick white smoke not unpleasantly pungent, and similar in odour to that of burning sugar. The residue which is but small, sinks into the coal. Starch emits a similar smoke, but leaves a more bulky residue. When exposed to a red heat, inulin burns with a vivid flame, and leaves a very small coaly residue.

When distilled, inulin yields a brown acid liquid, having the smell of pyromucous acid, but not a trace of oil.

When inulin is treated with nitric acid, it yields malic and oxalic acids, or acetic acid if too much nitric acid be employed. But no saclactic acid is formed as happens with the gums, neither is any of the waxy matter separated, which makes its appearance when starch is digested in nitric acid,

CHAP. X.

OF STARCH.

If a quantity of wheat flour be formed into a paste, and then held under a very small stream of water, knedding continually till the water runs off from it colourless, the flour by this process is divided into two distinct constituents. A tough substance of a dirty white colour, called *gluten*, remains in the hand; the water is at first milky but soon deposites a white powder, which is known by the name of *starch*.

The starch obtained by this process is not quite free from gluten. Hence it is not very white, and has not that crystallized appearance which distinguishes the starch of commerce. Manufacturers employ a more economical and more efficacious process. Wheat is steeped in water till it gives out a milky juice when squeezed, it is then put into coarse linen sacks which are subjected to pressure in a vessel of water till the whole starchy matter is separated. The sack and its contents are then removed. The water containing the starch gradually ferments. Vinegar and alcohol are formed in it, partly, no doubt, at the expence of the starch. The vinegar thus formed dissolves all the impurities, and leaves nothing behind but the starch. It is poured off, and the starch being edulcorated with water, is dried with a moderate heat. During the drying, it usually splits into columnar masses, which have a considerable degree of regularity.

Starch was well known to the ancients. According to Pliny, the method of manufacturing it was discovered by the inhabitants of Chios.

Starch has a fine white colour, and is usually concreted in four-sided prisms. It has scarcely any smell, and very little taste. When kept dry, it continues for a long time uninjured, though exposed to the air.

It does not dissolve in cold water, but very soon falls to powder, and forms a kind of emulsion. It dissolves in boiling water, and forms a kind of jelly, which may be diffused through boiling water: but when the mixture is allowed to stand a sufficient time, the starch slowly precipitates to the bottom. The subsidence takes place even when 90 parts of water are employed to dissolve one of starch; but, in that case, at least a month elapses before the starch begins to precipitate. The solution is glutinous in proportion to the quantity of starch. Linen dipt into it and suddenly dried, acquires a considerable degree of stiffness. When the solution is evaporated to dryness, a brittle opake mass is obtained, differing in appearance from common starch, but exhibiting nearly the same properties with re-agents. Hence the apparent difference is probably owing to a portion of water remaining united to the boiled starch. When the solution of starch is left exposed to damp air, it soon loses its consistency, acquires an acid taste, and becomes mouldy on the surface.

Starch does not dissolve, nor even fall to powder in alcohol. Neither does it dissolve in ether.

Neither oxygen gas nor the simple combustibles have any marked action on starch. The metals and their oxides have little affinity for it. Acetate of lead throws it down from water, but the superacetate has no effect upon it. According to Dr Bostock, it is precipitated also by oxymuriate of tin; but in my trials, I obtained no precipitate with that salt in a decoction containing one-ninetieth of its weight of starch. No other metallic salt tried produced a precipitate in this decoction.

Neither lime nor strontian water precipitate the decoction of starch; but barytes water throws down a copious white flaky precipitate. It is dissolved by muriatic acid, but appears again on standing, unless a considerable excess of acid be added. Neither muriate of barytes nor silicated potash occasion any precipitate in the decoction of starch.

When starch is triturated in a hot infusion of nutgalls, a complete solution is effected. This solution is transparent, and rather lighter coloured than the infusion of nutgalls employed. When this solution cools it becomes opake, and a copious curdy precipitate falls. A heat of 120° re-dissolves this precipitate and renders the solution transparent, but it is deposited again as the liquid cools. This property is characteristic of starch. The infusion of nutgalls throws it down from every solution, but the precipitate is re-dissolved by heating the liquid to 120°. The precipitate is a compound of tannin and starch, and is least soluble when composed of about three parts starch and two parts tannin. It has a brownish yellow colour, is semi-transparent, has an astringent taste, and feels glutionous between the teeth like gum.

When potash is triturated with starch and a little water added, the whole assumes, on standing, the appearance of a semi-transparent jelly. On adding water, an opal coloured solution is obtained, from which the starch is readily thrown down by an acid. When muriatic acid is employed, a peculiar aromatic odour is perceived. The decoction of starch is neither altered by potash, carbonate of potash nor ammonia.

When starch is thrown into any of the mineral acids, at first no apparent change is visible; but, if an attempt is made to reduce the larger pieces, while in acids, to powder, they resist it and feel exceedingly tough and adhesive. Sulphuric acid dissolves it slowly, and at the same time a smell of sulphuric acid is emitted, and such a quantity of charcoal evolved, that the vessel may be inverted without spilling any of the mixture. Diluted sulphuric acid dissolves starch when assisted by heat, and the starch may be again precipitated by means of alcohol.

Diluted nitric acid slowly dissolves starch, the acid acquires a green colour, and a small portion of white matter swims on the surface, on which the acid does not act. Alcohol throws down the starch from this solution. Concentrated nitric acid dissolves starch pretty rapidly, assuming a green colour, and emitting nitrous gas. The solution is never complete, nor do any crystals of oxalic acid appear unless heat be applied. In this respect starch differs from sugar, which yields oxalic acid even at the temperature of the atmosphere. When heat is applied to the solution of starch in nitric acid, both oxalic and malic acids are formed, but the undissolved substance still remains. When separated by filtration and afterwards edulcorated, this substance has the appearance of a thick oil not unlike tallow; but it dissolves readily in alcohol. When distilled, it yields acetic acid and an oil having the smell and consistence of tallow.

Strong muriatic acid dissolves starch slowly and without effervescence. When the starch does not exceed one-twentieth of the acid, the solution is colourless and transparent; but if we continue to add starch, a brown colour appears, and the acid loses a portion of its fluidity. Its peculiar smell is destroyed and replaced by the odour which may be perceived in corn mills. Acetic acid does not dissolve starch. The action of the other acids has not been tried.

Alcohol separates starch in part from its decoction. A solution of potash in alcohol occasions a copious white precipitate, which is re-dissolved on adding a sufficient quantity of water. A solution of sulphuret of potash in alcohol occasions a flaky precipitate in the decoction of starch. This precipitate has sometimes an orange colour.

When starch is thrown upon a hot iron it melts, blackens, frothes, swells and burns with a bright flame like sugar, emitting, at the same time, a great deal of smoke; but it does not explode, nor has it the caromel smell which distinguishes burning sugar. When distilled it yields water impregnated with an acid supposed to be the pyromucous, a little empyreumatic oil, and a great deal of carbonic acid and heavy inflammable air. The charcoal which it leaves burns easily when kindled in the open air, and leaves very little ashes.

Starch is contained in a great variety of vegetable substances; most commonly in their seeds or bulbous roots, but sometimes also in other parts. All the different species of corn contain a great proportion of it. There are obviously different varieties of starch possessing distinct properties. But hitherto these varieties have not been examined with such attention as to enable us to give a detailed description of each.

CHAP. XI.

OF INDIGO.

This valuable pigment, one of the capital manufactures of America, is obtained from the leaves of different species of plants: the *indigofera argentea* or *wild indigo*, the *indigofe-*

ra disperma or *Guatimala indigo*, and the *indigofera tinctoria* or *French indigo*, which yields the greatest quantity of indigo, and is therefore preferred by the planter, though its quality is said to be inferior to that of the indigo obtained from the two first species. In the West Indies the seeds are sown in March, in trenches about a foot asunder, and the plant comes into blossom, and is fit for cutting down in May. But in South America, six months elapse before it can be cut. In the West Indies four cuttings are often obtained from the same plant in the course of a year; but in America, never more than two, and often only one. The produce constantly diminishes after the first cutting, so that it is necessary to renew the plants for seed every year.

The plants are cut down with sickles, and laid in strata in the *steeper* till it is about three parts full. This is a large cistern of wood or mason work about 16 feet square. Here they are pressed down with planks, and loaded to prevent them from swimming, and covered with water to the height of four or five inches. Here they ferment, and the utmost attention is required to the process. If they be allowed to remain too long, the pigment is spoiled; and if the water be drawn off too soon, much of the indigo is lost. The temperature of 80° is said to answer best. The water acquires a green colour, a smell resembling that of ammonia is exhaled, and bubbles of carbonic acid are emitted. When the fermentation has continued long enough, the liquor is let out into a second cistern, placed lower than the first; this cistern is called the *battery*, and is commonly about 12 feet square, and four and a half deep. Here it is agitated for 15 or 20 minutes, by means of levers driven by machinery, till the flocculi beginning to separate give it a curdled appearance. A quantity of lime-water is now poured in, and the blue flocculi are allowed to subside. The water is then drawn off, and the pigment put to be drained in small linen bags, after which it is put into little square boxes, and allowed to dry in the shade.

Chevreul has shown that the indigo exists in the plant chiefly in the state of a white matter, which becomes blue when it combines with oxygen. Indigo may be obtained also from other plants, the *nerium tinctorium* for example, and the *isatis tinctoria*, or *woad*, a plant common enough in Britain. But the quantity obtained from this plant does not exceed one-tenth of what may be procured from the *indigofera*.

Indigo is a fine light friable substance of a deep blue colour. Its texture is very compact, and the shade of its surface varies according to the manner in which it has been prepared. The principal tints are copper, violet and blue. The lightest indigo is the best; but it is always mixed with foreign substances; scarcely one half even of the best indigo of commerce consisting of the pure pigment, The following substances were extracted by Chevreul from 100 parts of Guatimala indigo.

Ammonia, a trace	
Disoxygenized indigo	12
Green matter	30
Bitter matter, a trace	
Red matter	6
Carbonate of lime	2
Oxide of iron and alumina	2
Silica	3
Pure indigo	45
	100

Pure indigo has neither taste nor smell. It is insoluble in water in its usual state, but disoxygenized indigo is soluble in that liquid, as are likewise some of the foreign bodies with which indigo is usually mixed. When heated, indigo sublimes in a purple smoke, and may be obtained unaltered crystallized in needles. This purple smoke is characteristic of indigo.

Neither oxygen nor the simple combustible have any action on common indigo; but disoxygenized indigo readily combines with oxygen, and may be separated again from it without decomposition. In this respect it differs from almost all other vegetable substances, and approaches the properties of the simple combustibles and metals.

The fixed alkaline solutions have no effect upon indigo, except it be newly precipitated from a state of solution. In that case they dissolve it with facility. The solution has at first a green colour, which gradually disappears, and the natural colour of the indigo cannot be again restored. Hence we see that the alkalies when concentrated decompose indigo. Pure liquid ammonia acts in the same way. Even carbonate of ammonia dissolves precipitated indigo, and destroys its colour.

Lime water has scarcely any effect upon indigo in its usual state, but it dissolves precipitated indigo. The solution is at first green, but it becomes gradually yellow.

When diluted sulphuric acid is digested over indigo, it produces no effect except that of dissolving the impurities; but concentrated sulphuric acid dissolves it readily. One part of indigo, when mixed with eight parts of sulphuric acid, evolves heat, and is dissolved in 24 hours. The solution of indigo is well known in this country by the name of *liquid blue*. Bancroft calls it *sulphate of indigo*. While concentrated, it is opaque and black; but when diluted, it assumes a fine deep blue colour, and its intensity is such, that a single drop of the concentrated sulphate is sufficient to give a blue colour to many pounds of water. Bergman ascertained the effect or different reagents on this solution with great precision. His experiments threw light, not only on the properties of indigo, but upon the phenomena that take place when it is used as a dye-stuff.

From his experiments, it is obvious that all those substances which have a very strong affinity for oxygen give a green colour to indigo, and at last destroy it. Hence it is extremely probable, that indigo becomes green by giving out oxygen. Of course it owes its blue colour to that principle. This theory was first suggested by Mr Haussman, and still farther confirmed by Berthollet. Now it is only when green that it is in a state capable of being held in solution by lime, alkalies, &c. in which state it is applied as a dye to cloth. The cloth, when dipt into the vat containing it thus dissolved, combines with it, and the blue colour is restored by exposure to the atmosphere. It may be restored equally by plunging the cloth into oxymuriatic acid. Hence the restoration cannot but be ascribed to oxygen. Hence then the reason that sulphurous acid, the vegetable acids, sulphate of iron, give sulphate of indigo a green colour.

From these experiments, we see also that the colour of indigo is destroyed by the addition of those substances which part with oxygen very readily, as the black oxide of manganese. In that case the indigo is destroyed, for its colour cannot be again restored. When the sulphate of indigo is poured into boiling water, it affords a green-coloured solution; but with cold water a deep blue solution. What is called smoking sulphuric acid dissolves indigo much more readily than the pure acid, and evolves much more heat during the solution. Bucholz has shown, that by boiling sulphur in pure sulphuric acid, it acquires the property of dissolving indigo as readily as the smoking acid.

Nitric acid attacks indigo with great violence; the evolution of the abundance of heat and nitrous gas. When of the specific gravity 1·52, it even sets fire to indigo. When the acid is diluted, the action is still violent, unless the proportion of water be considerable. Mr Hatchett poured upon 100 grains of indigo an ounce of nitric acid diluted with an equal quantity of water. The action was so rapid, that he found it necessary to add another ounce of water. When the effervescence had nearly subsided, the liquid was placed on a sand bath for some days, and evaporated to dryness. Water poured upon the residuum dissolved a considerable portion of it, and formed a beautiful deep yellow solution of an intense bitter taste. This solution contains only a very small portion of oxalic acid; but with a solution of isinglass it forms a copious yellow insoluble precipitate, and of course contains a portion of artificial tannin. With ammonia crystals precipitate, consisting of *bitter principle* combined with ammonia.

When four parts of nitric acid are boiled upon one part of indigo, the pigment soon loses its colour, and is dissolved. The solution becomes yellow, and a thin layer of a resinous matter appears on the surface. If the process be now stopt, the resinous matter becomes thin by cooling. If this matter be removed, and the solution evaporated to the consistence of honey, redissolved in hot water and filtered, potash throws down yellow spicular crystals, consisting of *bitter principle* combined with potash. These crystals have the curious property of detonating with a purple light when wrapt up in paper and struck with a hammer; the resin, by treating it with fresh nitric acid, may be converted into the same bitter principle. If the process be stopt sooner than the point mentioned above, yellow crystals are obtained, which are more soluble in water, and which sublime in white needles, having all the properties of benzoic acid.

Muriatic acid does not act upon indigo in its common state, but it readily dissolves indigo precipitated from the sulphate, and forms a blue coloured solution. The same phenomena are exhibited by the phosphoric, acetic, tartaric acids, and probably by all except the acid supporters.

Oxymuriatic acid destroys the colour of indigo as readily as nitric acid, and obviously for the same reason.

Alcohol dissolves a small portion of indigo, but it gradually precipitates again unless *red matter* be present, in which case the solution is permanent.

Indigo is not acted upon by ether or oils, at least if the experiments of Bergman be accurate.

When indigo is mixed with bran, woad, and other similar substances which readily undergo fermentation, it assumes a green colour during the fermentation, and is then easily dissolved by lime or potash. It is by this process that it is usually rendered proper for dyeing.

CHAPTER XII.

OF GLUTEN.

If wheat-flour be kneaded into paste with a little water, it forms a tenacious elastic, soft, ductile mass. This is to be washed cautiously, by kneading it under a small jet of water till the water no longer carries off any thing, but runs off colourless; what remains behind is called *gluten*. It was discovered by Beccaria, an Italian philosopher, to whom we are indebted for the first analysis of wheat-flour.

Gluten, when thus obtained, is of a grey colour, exceedingly tenacious, ductile, and elastic, and may be extended to twenty times its original length. When very thin, it is of a whitish colour, and has a good deal of resemblance to animal tendon or membrane. Its smell is peculiar. It has scarce any taste, and does not lose its tenacity in the mouth.

When exposed to the air, it gradually dries; and when completely dry, it is pretty hard, brittle, slightly transparent, of a dark brown colour, and has some resemblance to *glue*.

Fresh gluten imbibes water, and retains a certain quantity of it with great obstinacy. To this water it owes its elasticity and tenacity. When boiled in water it loses both these properties.

When fresh gluten is macerated for a considerable time in cold water, the liquid becomes opaque, and contains small films suspended, which do not soon subside. By repeated filtrations it becomes transparent; but it holds in solution gluten, which renders it frothy, and gives it the property of precipitating when mixed with oxymuriatic acid or the infusion of nutgalls. Thus gluten is to a certain extent soluble in cold water. When the water is heated, the gluten separates in the state of yellow flakes.

When kept moist, it very soon begins to decompose, and to undergo a species of fermentation. It swells, and emits air-bubbles, which Proust has ascertained to consist of hydrogen and carbonic acid gases. It emits also a very offensive odour, similar to what is emitted by putrefying animal bodies. Cadet kept gluten in a vessel for a week in a damp room. Its surface became covered with byssi, the fermentation just mentioned had commenced, and the odour was distinctly acid. In 24 days, on removing the upper crust, the gluten was found converted into a kind of paste, of a greyish white colour, not unlike bird-lime. In that state he gave it the name of *fermented gluten*. It the gluten be still left to itself, it gradually acquires the smell and the taste of *cheese*. This curious fact was first ascertained by Rouelle junior. In that state it is full of holes, and contains the very same juices which distinguish some kinds of cheese. Proust ascertained that it contains ammonia and vinegar; bodies which Vauquelin detected in cheese; and ammonia robs both equally of their smell and flavour.

Fresh gluten does not sensibly dissolve in alcohol, which even throws down fresh gluten from water; yet in certain cases this liquid forms a solution of gluten in very small proportion.

When the *fermented* gluten of Cadet is triturated with a little alcohol into a mucilage, and then mixed with a sufficient quantity of that liquid, a portion of it is dissolved. This solution constitutes an excellent varnish, possessed of considerable elasticity. It may be spread over paper or wood; and when dry resists other bodies, as well as most varnishes. In this state, too, it may be employed to cement china; and triturated with paints, especially vegetable colours, it forms a very good ground. When this solution is mixed with a sufficient quantity of lime, it forms a very good lute; and bits of linen dipt in it adhere very strongly to other bodies.

Ether does does not sensibly dissolve gluten.

Acids act upon gluten differently according to the peculiar properties of each.

Concentrated acetic acid dissolves it readily in considerable quantity, and without altering its nature. The solution is muddy, but permanent; and the gluten may be thrown down by means of alkalies. This acid dissolves the fermented gluten of Cadet; and the solution may be substituted for the solution in alcohol as a varnish; but it does not answer to mix it with colours.

Concentrated sulphuric acid renders it violet coloured, and at last black; inflammable air escapes, and charcoal, water, and a portion of ammonia, are formed. When nitric cid is poured on it, and heat applied, there is a quantity f azotic gas emitted, and by continuing the heat, some little xalic acid is formed, and likewise malic acid, while a number of yellow-coloured oily flakes make their appearance in he solution.

Muriatic acid dissolves gluten with facility when its action s assisted by heat. When gluten is placed in oxymuriatic cid it softens, and seems to dissolve, but soon coagulates gain into yellow-coloured flakes, which become transparent nd greenish coloured by drying. When heated, they exhale xymuriatic acid, and assume the appearance of common luten. This acid has the property of precipitating gluten rom water in the state of yellowish white flakes.

Alkalies dissolve gluten when they are assisted by heat. The solution is never perfectly transparent. Acids precipitate the gluten from alkalies, but it is destitute of its elasticity. Alkalies, when much concentrated, form with it a kind of soap, converting it into oil and ammonia; which last is dissipated during the trituration.

Gluten is precipitated from water, and from some of its other solutions, by the infusion of nutgalls. The colour of the precipitate is usually yellowish brown, and it does not dissolve though the solution be heated.

When moist gluten is suddenly dried, it swells amazingly. Dry gluten, when exposed to heat, cracks, swells, melts, blackens, exhales a fetid odour, and burns precisely like feathers or horn. When distilled, there come over water impregnated with ammonia and an empyreumatic oil; the charcoal which remains is with difficulty reduced to ashes.

CHAP. XIII.

OF ALBUMEN.

Albumen is the term by which chemists have agreed to denote the *white of egg*, and all glary tasteless substances which, like it, have the property of coagulating into a white, opaque, tough, solid substance, when heated a little under the boiling point. This substance forms a constituent of many of the fluids of animal bodies; and when coagulated, it constitutes also an important part of their solids. Substances analogous to it had been noticed by chemists in the vegetable kingdom. Scheele affirmed, as early as 1780, that the greater number of plants contained a substance analogous to curd. Fourcroy, about the year 1790, announced the existence of albumen in a variety of plants; but Proust has since shown, that the substance which he took for albumen, and which had been already examined by Rouelle, was not possessed of the properties which characterise that animal matter. But Vauquelin has lately discovered albumen in abundance in the juice of the papaw tree; so that its existence as a vegetable principle cannot be disputed.

The *papaw tree*, the *carica papaya* of botanists, grows in Peru, &c. and in the Isle of France, where the milky juice that exudes from it is said to be employed with efficacy against the *Guinea worm*. Two specimens of this juice were brought from that island to Paris by Charpentier de Cossigny. In the one, the juice had been evaporated to dryness, and was in the state of an extract; in the other, the juice was preserved by being mixed with an equal bulk of rum. Both were subjected to a chemical analysis by Vauquelin. The first was of a yellowish white colour, and semitransparent. Its taste was sweetish. It had no smell, and was pretty solid; but attracted moisture when kept in a damp place. The second was reddish brown, and had the smell and taste of boiled beef. When the first specimen was macerated in cold water, the greatest part of it dissolved. The solution frothed with soap. The addition of nitric acid coagulated it, and rendered it white; and when boiled, it threw down abundance of white flakes. These flakes were coagulated albumen.

Other specimens of this juice, both in the liquid and dried state, have been examined more recently by Vauquelin, and likewise by Cadet.

The essential characters of albumen are the following:

In its natural state it is soluble in water, and forms a glary limpid liquid, having very little taste; which may be employed as a paste, and which forms a very shining varnish.

The solution is coagulated by acids, pretty much in the same way as milk is coagulated by the same re-agents.

When not too much diluted, it is coagulated also when heated to the temperature of 176°.

Albumen dissolved in water is precipitated in the state of brown flakes by the infusion of tan.

The solution is equally coagulated when mixed with alcohol.

Albumen is precipitated from water in the state of white powder by the salts of most of the white metals; such as silver, mercury, lead, tin, &c.

The juice of the papaw possessed all these properties. It therefore contained albumen. In few other vegetable productions has this substance been yet found in such abundance, or in a state in which its properties were so decidedly characteristic; but the resemblance between the curd of milk and albumen is very close, as we shall see afterwards. Now Proust has ascertained that *almonds*, and other similar kernels from which *emulsions* are made, contain a subst which has the properties of curd.

Albumen, when burnt, emits ammonia; and when treat with nitric acid, yields azotic gas. It evidently, then, contains azote. But as it is more properly an animal than a vegetable substance, I shall defer giving any farther account of its properties till I come to treat of animal bodies.

CHAP. XIV.

OF FIBRIN.

That peculiar substance which constitutes the fibrous part of the muscles of animals has been called *fibrin* by chemists. A substance resembling it, as it exists in the blood, has been detected by Vauquelin in the juice of the papaw tree; the same juice which contained albumen in such plenty. Fibrin then must be ranked among vegetable substances.

When the juice of the papaw is treated with water, the greatest part dissolves; but there remains a substance insoluble, which has a greasy appearance. It softens in the air, and becomes viscid, brown and semitransparent. When thrown on burning coals it melted, let drops of grease exude, emitted the noise of meat roasting, and produced a smoke which had the odour of fat volatilized. It left behind it no residue. This substance was the *fibrin*. The resemblance between the juice of the papaw and animal matter is so close, that one would be tempted to suspect some imposition, were not the evidence that it is really the juice of a tree quite unexceptionable.

The properties of fibrin are the following:

1. It is tasteless, fibrous, elastic, and resembles gluten.
2. It is insoluble in water and in alcohol.

3. It is not dissolved by diluted alkalies.

4. But acids dissolve it without difficulty.

5. With nitric acid it gives out much azotic gas.

6. When distilled it yields much carbonate of ammonia and oil.

7. It soon putrefies when kept moist, becomes green; but does not acquire any resemblance to cheese.

CHAP. XV.

OF THE BITTER PRINCIPLE.

Many vegetable substances have an intensely bitter taste, and on that account are employed in medicine, by brewers, &c. This is the case with the wood of the *quassia amara* and *excelsa*, the common *quassia* of the shops; with the roots of the *gentiana lutea,* common *gentian;* the leaves of the *humulus lupulus,* or *hop;* the bark and wood of the *spartium scoparium* or common broom; the flowers and leaves of the *anthemis nobilis* or *chamomile;* and many other substances. Some of these bodies owe their bitter taste to the presence of a peculiar vegetable substance differing from every other, which may be distinguished by the name of the *bitter principle.*

No chemical examination of this substance has been hitherto published; nor indeed are we in possession of any method of separating it from other bodies, or of ascertaining its presence. At the same time it cannot be doubted that it possesses peculiar characters; and its action on the animal economy renders it an object of importance.

I. When water is digested over *quassia* for some time, it acquires an intensely bitter taste and a yellow colour, but no smell. When water thus impregnated is evaporated to dryness in a low heat, it leaves a brownish-yellow substance, which retains a certain degree of transparency. It continues ductile for some time, but at last becomes brittle. This substance I shall consider as the bitter principle in a state of purity. If it contain any foreign body, it must be in a very minute proportion This substance I find to possess the following properties:

1. Its taste is intensely bitter. Colour brownish yellow.

2. When heated, it softens, and swells, and blackens; then burns away without flaming much, and leaves a small quantity of ashes.

3. Very soluble in water and alcohol.

4. Does not alter the colour of infusion of litmus.

5. Lime-water, barytes-water, and strontian-water, occasion no precipitate. Neither is any precipitate thrown down by silicated potash, aluminated potash, or sulphate of magnesia.

6. The alkalies occasion no change in the diluted solution of the bitter principle.

7. Oxalate of ammonia occasions no precipitate.

8. Nitrate of silver renders the solution muddy, and a very soft flaky yellow precipitate falls slowly to the bottom.

9. Neither corrosive sublimate nor nitrate of mercury occasion any precipitate.

10. Nitrate of copper, and the ammonial solution of copper, produce no change; but muriate of copper gives the white precipitate, which falls when this liquid salt is dropt into water.

11. Sulphate and oxymuriate of iron occasion no change.

12. Muriate of tin renders the solution muddy, but occasions no precipitate, unless the solution be concentrated; in that case a copious precipitate falls.

13. Acetate of lead occasions a very copious white precipitate; but the nitrate of lead produces no change.

14. Muriate of zinc occasions no change.

15. Nitrate of bismuth produces no change, though when the salt is dropt into pure water a copious white precipitate appears.

16. Tartar emetic produces no change; but when the muriate of antimony is used, the white precipitate appears, which always falls when this salt is dropt into pure water.

17. Muriate and arseniate of cobalt occasion no change.

18. Arseniate of potash produces no effect.

19. Tincture of nutgalls, infusion of nutgalls, gallic acid, occasion no effect.

These properties are sufficient to convince us that the bitter principle is a substance differing considerably from all the other vegetable principles. The little effect of the different re-agents is remarkable. Nitrate of silver and acetate of lead are the only two bodies which throw it down. This precipitation cannot be ascribed to the presence of muriatic acid; for if muriatic acid were present, nitrate of lead would also be thrown down.

II. Besides this purest species of bitter principle, it is probable that several others exist in the vegetable kingdom, gradually approaching by their qualities to the nature of *artificial tannin*. The second species is distinguished from the preceding, by the property which it has of striking a green colour with iron, and of precipitating that metal from concentrated solutions. Mr Chenevix separated a portion of it from coffee by the following process: He digested unburnt coffee in water, and filtered the liquid. It was then treated with muriate of tin. The precipitate was edulcorated, mixed with water, and treated with sulphureted hydrogen gas. The tin was thus precipitated, and the substance with which it had been combined was dissolved by the water. The liquid was then evaporated to dryness.

The substance thus obtained possessed the following properties:

1. Semitransparent like horn, and of a yellow colour.

2. When exposed to the air it does not attract moisture.

3. Soluble in water and in alcohol. The solution in water is semitransparent, and has a pleasant bitter taste. When the alkaline solutions are dropt into it, the colour becomes garnet red.

4. It is not precipitated from water by the alkaline carbonates. Sulphuric acid renders the solution brown, but produces no further change. Neither muriatic acid, nor phosphoric acid, nor the vegetable acids, produce any change on this solution.

5. The muriates of gold, platinum, and copper, occasion no change.

6. With solutions of iron it forms a fine green coloured liquid; and when concentrated, iron throws down a green-coloured precipitate. Indeed it is almost as delicate a test of iron as tan and gallic acid.

7. Muriate of tin throws down a copious yellow precipitate. This precipitate, and that by iron, are soluble in all acids, but they lose their colour.

8. Neither lime nor strontian water occasion any precipitate in the aqueous solutions of this substance; but barytes water occasions a brown precipitate.

9. Gelatine occasions no precipitate,

III. The Third species may be distinguished by the name of *artificial bitter principle*, as it has been formed by the action of nitric acid on various vegetable and animal substances. It was first obtained by Haussman while examining indigo, but he mistook its nature. Welther afterwards formed it by digesting silk in nitric acid, ascertained its properties, and gave it the name of *yellow bitter principle*; he is therefore to be considered as the real discoverer. Bartholdi afterwards procured it by treating the *white* willow with nitric acid. Mr Hatchett lately obtained it during his experiments on artificial tannin, by treating indigo with nitric acid; and about the same time Fourcroy and Vauquelin procured it by the same means, and examined its properties in detail. This substance possesses the following properties:

Its colour is a deep yellow, its taste intensely bitter. It is soluble both in water and alcohol, and has the property of dyeing silk, woollen cloth, and cotton, of a durable yellow colour. It crystallizes in elongated plates, and possesses many of the characters of an acid, combining readily with alkaline substances, and forming crystallizable salts. When potash is dropt into a concentrated solution of it, small yellow prismatic crystals are gradually deposited, consisting of bitter principle combined with potash. These crystals were examined by Welther, but it was Fourcroy and Vauquelin that ascertained their composition. They have a bitter taste, are not altered by exposure to the air, are less soluble than pure bitter principle. When thrown upon hot charcoal they burn like gunpowder, and detonate very loudly when struck upon an anvil, emitting a purple light. Ammonia dropt into the solution of bitter principle deepens its colour, and occasions a copious deposition of fine yellow spicular crystals. These are a combination of bitter principle and ammonia.

IV. Artificial tannin itself may be considered as approaching the bitter principle in many of its properties. Its taste is always intensely bitter, and the colour of the precipitates which it throws down from the metals, is similar to what takes place when artificial bitter principle is present. It is indeed possible, that the bitter taste may be owing not to the tannin, but to a portion of artificial bitter principle which may be always formed along with the tannin; but this has not been ascertained. It is well known that the bitter taste very easily overpowers and conceals all other tastes.

CHAP. XVI.

OF TANNIN.

Notwithstanding the numerous experiments made upon the infusion of nutgalls, we are not in possession of a process capable of furnishing tannin in a state of purity. Hence the obscurity which still hangs over its characters. The properties of this substance, as far as known, and the different methods of procuring it hitherto proposed by chemists, have been detailed in a preceding part of this work.

Like most other vegetable substances, it seems to be susceptible of different modifications. The following are the different species of tannin which have been hitherto noticed.

1. Tannin from nutgalls. This is the common species described in this work under the name of tannin. It precipitates iron black, and forms a firm insoluble brown precipitate with glue. The bark of oak, and most other astringent trees in this country, are supposed at present to contain this species of tannin.

2. The tannin which constitutes so large a proportion of catechu forms the second species. Its peculiar nature was first observed by Proust. It was afterwards more particularly examined by Mr Davy. It forms with iron an olive coloured precipitate.

3. The tannin of *kino* constitutes a third species. This substance is obtained from different vegetables. It was originally imported, as is supposed, from Africa; but at pre-

sent the common kino of the shops is, according to Dr Duncan, an extract from the *coccoloba urifera*, or *sea-side grape*, and is brought chiefly from Jamaica. But the finest kino is the product of different species of *eucalyptus*, particularly the *resinifera* or brown gum-tree of Botany Bay. It is an astringent substance of a dark red colour, and very brittle. It dissolves better in alcohol than water. The solution in the latter liquid is muddy; in the former transparent, and a fine crimson if sufficiently diluted. It throws down gelatine of a rose colour, and forms with salts of iron a deep green precipitate, not altered by exposure to the air.

4. The fourth variety of tannin is contained in *sumach*. This is a powder obtained by drying and grinding the shoots of the *rhus coriaria;* a shrub cultivated in the southern parts of Europe. The tan, which it contains in abundance, yields a precipitate with gelatine, which subsides very slowly, and remains in the state of a white magma without consistence.

5. The fifth variety, according to Proust, is to be found in the wood of the *morus tinctoria*, or *old fustic*, as the British dyers term it. This wood gives out an extract both to alcohol and water, which yields a precipitate with gelatine. A solution of common salt is sufficient to throw it down.

CHAP. XVII.

OF THE EXTRACTIVE PRINCIPLE.

The word *extract* was at first applied to all those substances which were extracted from plants by means of water, and which remained behind in the state of a dry mass when the water was evaporated; consequently it included gum, jelly, and several other bodies. But of late it has been confined by many to a substance which exists in many plants, and which may be obtained nearly in a state of purity, according to Hermbstadt, by infusing *saffron* in water for some time, filtrating the infusion, and evaporating it to dryness. But as the word *extract* occurs even in modern authors in its original sense, I shall rather denote this substance by the phrase *extractive principle,* to prevent ambiguity.

The difficulty of obtaining the extractive principle in a separate state, and the facility with which it alters its nature, have hitherto prevented chemists from examining it with that attention to which it is entitled. It was first particularly attended to by Rouelle; but it is to Fourcroy and Vauquelin that we are chiefly indebted for ascertaining its characters. The dissertation of Vauquelin in the *Journal de Pharmacie,* is by far the best account of extractive matter which has hitherto appeared. Many valuable facts and curious observations were published by Hermbstadt also in his dissertation on *extract.* But unfortunately the term has not been always taken by chemists in the same acceptation. Parmentier has lately published a dissertation on the *extracts* of vegetables taken in the loose and general sense of the word, which contains much information.

The extractive principle possesses the following properties:

Soluble in water, and the solution is always coloured. When the water is slowly evaporated, the extractive matter is obtained in a solid state and transparent; but when the evaporation is rapid the matter is opaque.

The taste of extractive is always strong; but it is very different according to the plant from which it is obtained.

Soluble in alcohol, but insoluble in ether.

By repeated solutions and evaporations, the extractive matter acquires a deeper colour, and becomes insoluble in water. This change is considered as the consequence of the absorption of the oxygen of the atmosphere, for which the extractive principle has a strong affinity. But if the solution be left to itself, exposed to the atmosphere, the extract is totally destroyed in consequence of a kind of putrefaction which speedily commences.

When oxymuriatic acid is poured into a solution containing extractive, a very copious dark yellow precipitate is thrown down, and the liquid retains but a light lemon colour. These flakes are the oxygenized *extractive*. It is now insoluble in water; but hot alcohol still dissolves it.

The extractive principle unites with alumina, and forms with it an insoluble compound. Accordingly, if sulphate or muriate of alumina be mixed with a solution of extractive, a flaky insoluble precipitate appears, at least when the liquid is boiled; but if an excess of acid be present, the precipitate does not always appear.

It is precipitated from water by concentrated sulphuric acid, muriatic acid, and probably by several other acids. When the experiment is made with sulphuric acid, the fumes of vinegar generally become sensible.

Alkalies readily unite with extractive, and form compounds which are insoluble in water.

The greater number of metallic oxides form insoluble compounds with extractive. Hence many of them, when thrown into its solution, are capable of separating it from water. Hence also the metallic salts mostly precipitate extractive. Muriate of tin possesses this property in an eminent degree. It throws down a brown powder perfectly insoluble, composed of the oxide of tin and vegetable matter.

If wool, cotton, or thread, be impregnated with alum, and then plunged into a solution of extractive, they are dyed of a fawn colour, and the liquid loses much of its extractive matter. This colour is permanent. The same ef-

fect is produced if muriate of tin be employed instead of alum. This effect is still more complete if the cloth be soaked in oxymuriatic acid, and then dipt into the infusion of extractive. Hence we see that the extractive matter requires no other mordant than oxygen to fix it on cloth.

When distilled, extractive yields an acid liquid impregnated with ammonia.

It cannot be doubted that there are many different species of extractive matter; though the difficulty of obtaining each separately has prevented chemists from ascertaining its nature with precision. Extracts are usually obtained by treating the vegetable substance from which they are to be procured with water, and then evaporating the watery solution slowly to dryness. All extracts obtained by this method have an acid taste, and redden the infusion of litmus. They all yield a precipitate while liquid if they are mixed with ammonia. This precipitate is a compound of lime and insoluble extractive. Lime always causes them to exhale the odour of ammonia. It has been ascertained that the extractive principle is more abundant in plants that have grown to maturity than in young plants.

CHAP. XVIII.

OF THE NARCOTIC PRINCIPLE.

It has been long known that the milky juices which exude from certain plants, as the poppy, lettuce, &c. and the infusions of others, as of the leaves of the *digitalis purpurea*, have the property of exciting sleep, or, if taken in large enough dozes, of inducing a state resembling apoplexy, and terminating in death. How far these plants owe these properties to certain common principles which they possess is not known;

though it is exceedingly probable that they do. But as a *peculiar substance* has been detected in *opium*, the most noted of the narcotic preparations, which possesses narcotic properties in perfection, we are warranted, till further experiments elucidate the subject, to consider it as the *narcotic principle*, or at least as one species of the substances belonging to this genus.

Opium is obtained from the *papaver album*, or white poppy, a plant which is cultivated in great abundance in India and the East. The poppies are planted in a fertile soil and well watered. After the flowering is over, and the seed capsules have attained nearly their full size, a longitudinal incision is made in them about sun-set for three or four evenings in succession. From these incisions there flows a milky juice, which soon concretes, and is scraped off the plant and wrought into cakes. In this state it is brought to Europe.

Opium, thus prepared, is a tough brown substance, has a peculiar smell, and a nauseous bitter acrid taste. It is a very compound substance, containing sulphate of lime, sulphate of potash, an oil, a resinous body, an extractive matter, gluten, mucilage, &c. besides the peculiar narcotic principle, to which, probably, it owes its virtues as a narcotic.

When water is digested upon opium, a considerable portion of it is dissolved, the water taking up several of its constituents. When this solution is evaporated to the consistence of a syrup, a gritty precipitate begins to appear, which is considerably increased by diluting the liquid with water. It consists chiefly of three ingredients; namely, resin, oxygenized extractive, and the peculiar narcotic principle, which is crystallized. When alcohol is digested on this precipitate, the resin and narcotic substance are taken up, while the oxygenized extractive remains behind. The narcotic principle falls down in crystals as the solution cools, still however co-

loured with resin. But it may be obtained tolerably pure by repeated solutions and crystallizations.

Water is incapable of dissolving the whole of opium. What remains behind still contains a considerable portion of narcotic principle. When alcohol is digested on this residuum, it acquires a deep red colour; and deposites, on cooling, crystals of narcotic principle, coloured by resin, which may be purified by repeated crystallizations. The narcotic principle obtained by either of these methods possesses the following properties.

Its colour is white. It crystallizes in rectangular prisms with rhomboidal bases. It has neither taste nor smell.

It is insoluble in cold water, soluble in about 400 parts of boiling water, but precipitates again as the solution cools. The solution in boiling water does not affect vegetable blues.

It is soluble in 24 parts of boiling alcohol and 100 parts of cold alcohol. When water is mixed with the solution, the narcotic principle precipitates in the state of a white powder.

Hot ether dissolves it, but lets it fall on cooling.

When heated in a spoon it melts like wax. When distilled it froths and emits white vapours, which condense into a yellow oil. Some water and carbonate of ammonia pass into the receiver; and at last carbonic acid gas, ammonia, and carbureted hydrogen gas, are disengaged. There remains a bulky coal, which yields traces of potash. The oil obtained by this process is viscid, and has a peculiar aromatic smell and acrid taste.

It is very soluble in all acids. Alkalies throw it down from these solutions in the state of a white powder.

Alkalies render it rather more soluble in water. When they are saturated with acids, the narcotic principle falls down in the state of a white powder, which is re-dissolved by adding an excess of acid.

Volatile oils, while hot, dissolve it; but, on cooling, they let it fall in an oleagenous state at first, but it gradually crystallizes.

When treated with nitric acid, it becomes red and dissolves; much oxalic acid is formed, and a bitter substance remains behind.

When potash is added to the aqueous solution of opium, the narcotic principle is thrown down; but it retains a portion of the potash.

Its solubility in water and alcohol, when immediately extracted from opium, seems to be owing to the presence of *resin* and *extractive matter*, both of which render it soluble.

It possesses the properties of opium in perfection. Dérosne tried it upon several dogs, and found it more powerful than opium. Its bad effects were counteracted by causing the animals to swallow vinegar. This substance is known to be of equal service in counteracting the effects of opium. Dérosne supposes that the efficacy of vinegar may be owing to the readiness with which it dissolves the narcotic principle.

CHAP. XIX.

OF OILS.

There are two species of oils; namely, *fixed* and *volatile*; both of which are found abundantly in plants.

1. Fixed oil is only found in the seeds of plants, and is almost entirely confined to those which have two cotyledons; as linseed, almonds, beech root, poppy seed, rape-seed, &c. Sometimes, though rarely, it is found in the pulp which surrounds the stone of certain fruits. This is the case with the olive, which yields the most abundant and most valuable

fect is produced if muriate of tin be employed instead of alum. This effect is still more complete if the cloth be soaked in oxymuriatic acid, and then dipt into the infusion of extractive. Hence we see that the extractive matter requires no other mordant than oxygen to fix it on cloth.

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It cannot be doubted that there are many different species of extractive matter; though the difficulty of obtaining each separately has prevented chemists from ascertaining its nature with precision. Extracts are usually obtained by treating the vegetable substance from which they are to be procured with water, and then evaporating the watery solution slowly to dryness. All extracts obtained by this method have an acid taste, and redden the infusion of litmus. They all yield a precipitate while liquid if they are mixed with ammonia. This precipitate is a compound of lime and insoluble extractive. Lime always causes them to exhale the odour of ammonia. It has been ascertained that the extractive principle is more abundant in plants that have grown to maturity than in young plants.

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Opium, thus prepared, is a tough brown substance, has a peculiar smell, and a nauseous bitter acrid taste. It is a very compound substance, containing sulphate of lime, sulphate of potash, an oil, a resinous body, an extractive matter, gluten, mucilage, &c. besides the peculiar narcotic principle, to which, probably, it owes its virtues as a narcotic.

When water is digested upon opium, a considerable portion of it is dissolved, the water taking up several of its constituents. When this solution is evaporated to the consistence of a syrup, a gritty precipitate begins to appear, which is considerably increased by diluting the liquid with water. It consists chiefly of three ingredients; namely, resin, oxygenized extractive, and the peculiar narcotic principle, which is crystallized. When alcohol is digested on this precipitate, the resin and narcotic substance are taken up, while the oxygenized extractive remains behind. The narcotic principle falls down in crystals as the solution cools, still however co-

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called *bleaching*, the yellow colour of the wax disappears, and it becomes very white. Bleached wax is not affected by the air.

The specific gravity of unbleached wax varies from 0·9000 to 0·9650; that of white wax from 0·8203 to 0·9662.

Wax is insoluble in water; nor are its properties altered though kept under that liquid.

When heat is applied to wax it becomes soft; and at the temperature of 142°, if unbleached, or of 155° if bleached, it melts into a colourless transparent fluid, which concretes again, and resumes its former appearance as the temperature diminishes. If the heat be still farther increased, the wax boils and evaporates; and if a red heat be applied to the vapour, it takes fire and burns with a bright flame. It is this property which renders wax so useful for making candles.

Wax is scarcely acted on by alcohol when cold, but boiling alcohol dissolves it.

Ether has but little action on wax while cold; but when assisted by heat, it takes up about one-twentieth of its weight of it, and lets the greatest part precipitate on cooling.

Wax combines readily with fixed oils when assisted by heat, and forms with them a substance of greater or less consistency according to the quantity of oil. This composition, which is known by the name of *cerate*, is much employed by surgeons.

The volatile oils also dissolve wax when heated. This is well known, at least, to be the case with oil of turpentine. A part of the wax precipitates usually as the solution cools, but of a much softer consistence than usual, and therefore containing oil.

The fixed alkalies combine with it, and form a compound which possesses all the properties of common soap. When boiled with a solution of fixed alkalies in water, the liquid becomes turbid, and after some time the soap separates and swims on the surface. It is precipitated from the alkali by acids in the state of flakes, which are the wax very little altered in its properties.

The acids have but little action on wax; even oxymuriatic acid, which acts so violently on most bodies, produces no other change on it than that of rendering it white. This property which wax possesses, of resisting the action of acids, renders it very useful as a lute to confine acids properly in vessels, or to prevent them from injuring a common cork.

Mr Lavoisier contrived to burn wax in oxygen gas. The quantity of wax consumed was 21·9 grains. The oxygen gas employed in consuming that quantity amounted to 66·55 grains. Consequently the substances consumed amounted to 88·45 grains. After the combustion, there were found in the glass vessel 62·58 grains of carbonic acid, and a quantity of water, which was supposed to amount to 25·87 grains. These were the only products.

From this experiment he concluded that 100 parts of wax are composed of

82 28 carbon
17·72 hydrogen

100·000

The myrtle wax of North America is obtained from the *myrica cerifera*. The *myrica cerifera* is a shrub which grows abundantly in Louisiana and other parts of North America. It produces a berry about the size of a pepper corn. A very fertile shrub yields nearly seven pounds. From the observations of Cadet, we learn that the wax forms the outer covering of the berries. The wax thus obtained is of a pale green colour. Its specific gravity is 1·0150. It melts at the temperature of 109°: when strongly heated it burns with a white flame, produces little smoke, and during the combustion emits an agreeable aromatic odour. Water does not act upon it. Alcohol, when hot, dissolves one-tenth of its weight, but lets most of it fall again on cooling. Hot ether dissolves about one-fourth of its weight; and when slowly cooled, deposites it in crystalline plates, like spermaceti. The ether acquires a green colour, but the wax becomes nearly white. Oil of turpentine, when assisted by heat, dissolves it sparingly. Alkalies act upon it nearly as on bees wax. The same remark applies to acids. Sulphuric acid, when assisted by heat, dissolves about one-twelfth of its weight, and is converted into a thick dark brown mass.

The Chinese extract a wax from various vegetables, which they manufacture into candles, and of which they form many delicate ornaments which are brought to Europe.

CHAP. XXI.

CAMPHOR.

THE substance called *camphor*, though unknown to the Greeks and Romans, seems to have been long known in the East. When it was first brought to Europe does not appear, though it seems to have been introduced by the Arabians.

It comes to Europe chiefly from Japan. It is obtained from the *laurus camphora*, a tree common in the East, by distilling the wood along with water in large iron pots, on which are fitted earthen heads stuffed with straw. The camphor sublimes, and concretes upon the straw in the form of a grey powder. It is afterwards refined in Holland by a second sublimation. The vessels are of glass, and somewhat of the shape of a turnip, with a small mouth above loosely covered with paper. According to Ferber, about one-fourth of pounded chalk is mixed with crude camphor; but others assure us that there is no addition whatever employed.

Camphor thus confined is a white brittle substance, having a peculiar aromatic odour, and a strong hot acrid taste. Its specific gravity is 0·9887.

It is not altered by atmospheric air; but it is so volatile, that if it be exposed during warm weather in an open vessel, it evaporates completely. When sublimed in close vessels it crystallizes in hexagonal plates or pyramids.

It is insoluble in water; but it communicates to that liquid a certain portion of its peculiar odour.

It dissolves readily in alcohol, and is precipitated again by water. According to Neumann, well rectified alcohol dissolves three-fourths of its weight of camphor. By distillation the alcohol passes over first, and leaves the camphor. This property affords an easy method of purifying camphor. Dissolve the camphor in alcohol, distil off the spirit, and melt the camphor into a cake in a glass vessel.

Camphor is soluble also in oils, both fixed and volatile. If the solution be made by means of heat, as it cools part of the camphor precipitates, and assumes the form of plumose or feather-like crystals.

Camphor is not acted on by alkalies, either pure or in the state of carbonates. Pure alkalies indeed seem to dissolve a little camphor; but the quantity is too small to be perceptible by any other quality than its odour. Neither is it acted on by any of the neutral salts which have hitherto been tried.

Acids dissolve camphor without effervescence, and in general it may be precipitated unaltered from the recent solution.

When heat is applied to camphor it is volatilized. If the heat be sudden and strong, the camphor melts before it evaporates; and it melts, according to Venturi, at the temperature of 300°; according to Romieu, at 421°. It catches fire very readily, and emits a great deal of flame as it burns, but it leaves no residuum. It is so inflammable that it continues to burn even on the surface of water. When camphor is set on fire in a large glass globe filled with oxygen gas, and containing a little water, it burns with a very bright flame, and produces a great deal of heat. The inner surface of the glass is soon covered with a black powder, which has all the properties of charcoal; a quantity of carbonic acid gas is evolved; the water in the globe acquires a strong smell, and is impregnated with carbonic acid and camphoric acid.

There are several species of camphor which have been examined by chemists, and which differ considerably from each other in their properties. The most remarkable are *common camphor*, the *camphor of volatile oils*, and the *camphor* obtained by treating *oil of turpentine* with *muriatic acid.*

Common camphor, obtained by distillation from the *laurus camphora*, is the substance which has been described in the preceding part of this Chapter. In Borneo and Sumatra camphor is procured from the *laurus sumatrensis*; but as none of this camphor is brought to Europe, we do not know how far it agrees with common camphor in its properties. The *laurus cinnamomum* likewise yields camphor.

The second species of camphor seems to exist in a great variety of plants, and is held in solution by the volatile oils extracted from them. Neumann obtained it from oils of thyme, marjoram, cardomum; Hermann, from oils extracted from various species of mint. Cartheuser obtained it from the roots of the *maranta galanga*, *kæmpferia rotunda*, *amomum zinziber*, *laurus cassia*, and rendered it probable that it is contained in almost all the labiated plants. It has been supposed to exist in these plants combined with volatile oil. Proust has shown how it may be extracted, in considerable quantity, from many volatile oils.

From the observations of Mr John Brown, there is reason to believe that the camphor from oil of thyme differs from common camphor in several respects. It does not appear to form a liquid solution either with nitric or sulphuric acid; nor is it precipitated from nitric acid in powder like common camphor, but in a glutinous mass.

The artificial camphor yielded by oil of turpentine, when saturated with muriatic acid gas, was discovered by Mr Kind, apothecary in Eutin, while employed in making a medicine called the *liquor arthriticus Pottii.* He put a quantity of oil of turpentine into a Woulfe's bottle, and caused a current of muriatic acid gas, separated from common salt by sulphuric acid, to pass through it. The salt used was of the same weight with the oil of turpentine. At first the oil became yellow, then brown, and at last became almost solid, from the formation of a great number of crystals in it, which possessed the properties of camphor.

The proportion of muriatic gas found to answer best, is what can be separated by sulphuric acid and heat from a quantity of common salt equal in weight to the oil of turpentine employed. The camphor produced amounts nearly to one-half of the oil of turpentine.

The camphor thus produced was very white; it had a peculiar odour, in which that of the oil of turpentine could be distinguished. When washed with water, it became beautifully white, and gave no longer signs of containing an acid, but still had the smell of oil of turpentine. Water containing some carbonate of potash deprived it of part of this odour, but not the whole. When mixed with its own weight of charcoal powder, wood-ashes, quicklime, or porcelain clay, and sublimed, it was obtained in a state of purity.

Its smell when pure resembles that of common camphor, but is not so strong. Its taste also resembles that of camphor. It swims on water, to which it commnnicates its taste, and burns upon its surface. It dissolves completely in alcohol, and is precipitated by water. Nitric acid, of the specific gravity 1·261, had no action on it, though it readily dissolves common camphor; but concentrated nitric acid dissolves it with the disengagement of nitrous gas; and water does not precipitate it from its solution as it does common camphor. Acetic acid does not dissolve it. When heated it sublimes without decomposition; and when set on fire it burns like camphor.

CHAP. XXII.

OF BIRD-LIME.

The vegetable principle to which I give the name of *bird-lime*, was first examined by Vauquelin, who found it possessed of properties different from every other. It was found collected on the epidermis of a plant brought to Europe by Michaud, and called *robinia viscosa* by Cels; constituting a viscid substance, which made the fingers adhere to the young twigs. From the late analysis of *bird-lime* by Bouillon la Grange, it is obvious that it owes its peculiar properties to the presence of an analogous substance, which indeed constitutes the essential part of that composition. Hence the reason why I have given the name of *bird-lime* to the principle itself.

Natural bird-lime (or that which exudes spontaneously from plants), possesses the following properties:

Its colour is green; it has no sensible taste or smell; is extremely adhesive; softens by the heat of the fingers, ad sticks to them with great obstinacy. When heated it elts, swells up, and burns with a considerable flame, aving a bulky charcoal behind it. It does not dissolve water; alcohol has but little action on it, especially hen cold. By the assistance of heat it dissolves a poron of it; but on cooling, allows the greatest part to preipitate again. When exposed to the air it continues glunous, never becoming hard and brittle like the resins.

It combines readily with oils. Ether is its true solvent, issolving it readily without the assistance of heat. The olution is of a deep green colour. The alkalies do not ombine with it; the effect of the acids was not tried. hese properties are sufficient to distinguish bird-lime from very other vegetable principle.

Artificial bird-lime is prepared from different substances n different countries. The berries of the misletoe are said to have been formerly employed. They were pounded, boiled in water, and the hot water poured off. At preent bird-lime is usually prepared from the middle bark of he holly. The process followed in England, as described by Geoffroy, is as follows: The bark is boiled in water seven or eight hours till it becomes soft. It is then laid in quantities in the earth, covered with stones, and left to ferment or rot for a fortnight or three weeks. By this fermentation it changes to a mucilaginous consistency. It is then taken from the pits, pounded in mortars to a paste and well washed with river water. Bouillon la Grange informs us, that at Nogent le Rotrou bird-lime is made by cutting the middle bark of the holly into small pieces, fermenting them in a cool place for a fortnight, and then boiling them in water, which is afterwards evaporated. At Commerci various other plants are used.

Its colour is greenish, its flavour sour, and its consistence gluey, stringy, and tenacious. Its smell is similar to that of linseed oil. When spread on a glass plate, and exposed to the air and light it dries, becomes brown, loses its viscidity, and may be reduced to powder; but when water is added to it, the glutinous property returns. It reddens vegetable blues.

When gently heated it melts, and emits an odour like that of animal oils. When heated on red hot coals, it burns with a lively flame, and gives out a great deal of smoke, leaving a white ash, composed of carbonate of lime, alumina, iron, sulphate, and muriate of potash.

Water has little action on bird-lime. When boiled in water the bird-lime becomes more liquid, but recovers its original properties when the water cools. The water, by this treatment, acquires the property of reddening vegetable blues, and when evaporated leaves a mucilaginous substance, which may be likewise separated by alcohol.

A concentrated solution of potash forms with bird-lime a whitish magma, which becomes brown by evaporation, while ammonia separates. The compound thus formed is less viscid than bird-lime, and in smell and taste resembles soap. In alcohol and water it dissolves almost completely and possesses properties similar to those of soap.

Weak acids soften bird-lime, and partly dissolve it; strong acids act with more violence. Sulphuric acid renders it black; and when lime is added to the solution, acetic acid and ammonia separate. Nitric acid cold has little effect; but when assisted by heat it dissolves the bird-lime; and the solution, when evaporated, leaves behind it a hard brittle mass. By treating this mass with nitric acid, a new solution may be obtained, which by evaporation yields malic and oxalic acids, and a yellow matter which possesses several of the properties of wax. Cold muriatic acid does not act on bird-lime; hot muriatic acid renders it black.

h solutions of pure potash, or soda. Every other resin
s dissolved as well as *rosin*.

These alkaline solutions of resins have the properties of
p, and may be employed as detergents. When mixed
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Ammonia acts but imperfectly upon resins, and does not
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tain degree of transparency, and a colour most commonly inclining to yellow. Their taste is more or less acrid, and not like that of volatile oils; but they have no smell unless they happen to contain some foreign body. They are all heavier than water. They are all non-conductors of electricity; and when excited by friction, their electricity is negative.

Their specific gravity varies considerably.

When exposed to heat they melt; and if the heat be increased they take fire, and burn with a strong yellow flame emitting at the same time a vast quantity of smoke.

They are all insoluble in water whether cold or hot; but when they are melted along with water, or mixed with volatile oil, and then distilled with water, they seem to unite, with a portion of that liquid; for they become opaque, and lose much of their brittleness. This at least is the case with common rosin.

They are all, with a few exceptions, soluble in alcohol, especially when assisted by heat. The solution is usually transparent; and when the alcohol is evaporated, the resin is obtained unaltered in its properties.

Several of them are soluble in fixed oils, especially in the drying oils. The greater number are soluble in the volatile oils; at least in oil of turpentine, the one commonly employed.

Mr Hatchett first examined the action of fixed alkalies on resins, and ascertained, contrary to the received opinion of chemists, that alkaline leys dissolve them with facility. He reduced a quantity of common rosin to powder, and gradually added it to a boiling lixivium of carbonate of potash; a perfect solution was obtained of a clear yellow colour, which continued after long exposure to the air. The experiment succeeded equally with carbonate of soda, and with solutions of pure potash, or soda. Every other resin was dissolved as well as *rosin*.

These alkaline solutions of resins have the properties of soap, and may be employed as detergents. When mixed with an acid, the resin is separated in flakes, usually of a yellow colour, and not much altered in its nature.

Ammonia acts but imperfectly upon resins, and does not form a complete solution of any of those bodies hitherto tried.

It was the received opinion of chemists that acids do not act upon resins. Mr Hatchett first ascertained this opinion also to be erroneous, and showed that most of the acids dissolve resins with facility, producing different phenomena according to circumstances.

When sulphuric acid is poured upon any of the resins in powder, it dissolves them in a few minutes. At first the solution is transparent, of a yellowish brown colour, and of the consistency of a viscid oil, and the resin may be precipitated nearly unaltered by the addition of water. If the solution be placed on a sand bath, its colour becomes deeper, sulphurous acid gas is emitted, and it becomes very thick, and of an intense black.

Nitric acid likewise dissolves the resins with facility, but not without changing their nature. Mr Hatchett was first led to examine the action of this acid on resins, by observing that resins are thrown down by acids from their solutions in alkalies in the state of a curdy precipitate; but when nitric acid is added in excess, the whole of the precipitate is re-dissolved in a boiling heat. He poured nitric acid of the specific gravity 1·38, on powdered rosin in a tubulated retort; and by repeated distillation formed a complete solution of a brownish yellow colour. The solution takes place much sooner in an open matrass than in close vessels. The solution continues permanent, though left exposed to the air. It becomes turbid when water is added; but when the mixture is boiled, the whole is redissolved.

When the digestion of nitric acid upon a resinous substance is continued long enough, and the quantity of acid is sufficient, the dissolved resin is completely changed; it is not precipitated by water; and by evaporation, a viscid substance of a deep yellow colour is obtained, equally soluble in water and alcohol, and seemingly intermediate between resin and extractive. If the abstraction of nitric acid be repeated, this substance gradually assumes the properties of artificial tannin. Thus it appears that nitric acid gradually alters the nature of resin, producing a suite of changes which terminate in artificial tannin, upon which nitric acid has no action.

Muriatic acid and acetic acid dissolve resin slowly, and it may be precipitated again from them unaltered.

When resins are subjected to destructive distillation, we obtain carbureted hydrogen and carbonic acid gas, a very small portion of acidulous water, and much empyreumatic oil. The charcoal is light and brilliant, and contains no alkali.

II. Having now described the general properties of resinous bodies, it will be proper to take a more particular view of those of them which are of the most importance, that we may ascertain how far each possesses the general characters of resins, and by what peculiarities it is distinguished from the rest. The most distinguished of the resins are the following.

1. *Rosin.*—This substance is obtained from different species of *fir*; as the *pinus abies, sylvestris, larix, balsamea.* It is well known that a resinous juice exudes from the *pinus sylvestris,* or common Scotch fir, which hardens into tears. The same exudation appears in the *pinus abies,* or spruce fir. These tears constitute the substance called *thus,* or common

Frankincense. When a portion of bark is stripped off these trees, a liquid juice flows out, which gradually hardens. This juice has obtained different names according to the plant from which it comes. The *pinus sylvestris* yields *common turpentine;* the *larix, Venice turpentine;* the *balsamea, balsam of Canada,* &c. All these juices which are commonly distinguished by the name of turpentine, are considered as composed of two ingredients; namely, oil of turpentine and rosin.

2. *Mastich.*—This resin is obtained from the *pistacia lentiscus;* a tree which grows in the Levant, particularly in the island of Chios. When transverse incisions are made into this tree, a fluid exudes, which soon concretes into yellowish semitransparent brittle grains. It softens when kept in the mouth, but imparts very little taste. When heated, it melts and exhales a fragrant odour. Its taste is slight, but not unpleasant. In Turkey great quantities of it are said still to be chewed for sweetening the breath, and strengthening the gums. It is to this use of the resin as a masticatory that it is supposed to owe its name Mastich does not dissolve completely in alcohol; a soft elastic substance separates during the solution. The nature of this insoluble portion was first examined by Kind, who found it possessed of all the properties of caoutchouc. These experiments have lately been repeated by Mr Mathews with a similar result. Mr Brande, however, has observed, that when this insoluble substance is dried, it becomes brittle, in which respect it differs from caoutchouc. He has observed also, that by passing a current of oxymuriatic gas through the alcoholic solution of mastich, a tough elastic substance is thrown down, precisely similar to the original insoluble portion.

3. *Sandarach.*—This resin is obtained from the *juniperus communis* or common juniper. It exudes spontaneously, and is usually in the state of small round tears of a brown

colour, and semitransparent, not unlike mastich, but ra more transparent and brittle. When chewed it does soften as mastish does, but crumbles to powder. Mr M thews found it almost completely soluble in eight times i weight of alcohol. The residue was extraneous matter. I does not dissolve in tallow or oil, as common resin does.

4. *Elemi.*—This resin is obtained from the *amyris elemifera;* a tree which grows in Canada and Spanish America. Incisions are made in the bark during dry weather, and the resinous juice which exudes is left to harden in the sun. It comes to this country in long roundish cakes wrapped in flag leaves. It is of a pale yellow colour, semitransparent; at first softish, but it hardens by keeping. Its smell is at first strong and fragrant, but it gradually diminishes.

5. *Tacamahac.*—This resin is obtained from the *fag* *octandra,* and likewise, it is supposed, from the *populus ba* *samifera.* It comes from America in large oblong masses wrapt in flag leaves. It is of a light brown colour, very brittle, and easily melted when heated. When pure it has an aromatic smell between that of lavender and musk.

6. *Animé.*—This resin is obtained from the *hymenaea courbaril* or locust tree, which is a native of North America. Animé resembles copal very much in its appearance; but is readily soluble in alcohol, which copal is not: this distinguishes them. It is said to be very frequently employed in making varnishes. Alcohol dissolves it completely.

7. *Ladanum* or *labdanum.*—This resin is obtained from the *cystus creticus,* a shrub which grows in Syria and the Grecian Islands. The surface of this shrub is covered with a viscid juice, which, when concreted, forms ladanum. It is collected while moist by drawing over it a kind of rake with thongs fixed to it. From these thongs it is afterwards scraped with a knife. It is always mixed with dust and sand, sometimes in great abundance. The best is in dark coloured

masses, almost black, and very soft, having a fragrant odour and a bitterish taste. The impurities even in the best kinds, amount to about one-fourth.

8. *Botany Bay resin.*—This resin is said to be the produce of the *acaroïs resinifera;* a tree which grows abundantly in New Holland, especially near Botany Bay. Specimens of it were brought to London about the year 1799, where it was tried as a medecine.

The resin exudes spontaneously from the trunk of the singular tree which yields it, especially if the bark be wounded. It is at first fluid, but becomes gradually solid when dried in the sun. It consists of pieces of various sizes of a yellow colour, unless when covered with a greenish grey crust. It is firm, yet brittle; and when pounded, does not stick to the mortar nor cake. In the mouth it is easily reduced to powder without sticking to the teeth. It communicates merely a slight sweetish astringent taste. When moderately heated, it melts; on hot coals it burns to a coal, emitting a white smoke, which has a fragrant odour somewhat like storax. When thrown into the fire, it increases the flame like pitch. It communicates to water the flavour of storax, but is insoluble in that liquid. When digested in alcohol, two-thirds dissolve: the remaining third consists of one part of extractive matter, soluble in water, and having an astringent taste; and two parts of woody fibre and other impurities, perfectly tasteless and insoluble. The solution has a brown colour, and exhibits the appearance and the smell of a solution of benzoin. Water throws it down unaltered. When distilled, the products were water and empyreumatic oil, and charcoal; but it gives no traces of any acid, alkali, or salt, not even when distilled with water.

9. *Copal.*—This substance, which deserves particular attention from its importance as a varnish, and which at first sight seems to belong to a distinct class from the resins, is

obtained, it is said, from the *rhus copallinum*, a tree which is a native of North America; but the best sort of copal is said to come from Spanish America, and to be the produce of different trees. No less than eight species are enumerated by Hernandez.

Copal is a beautiful white resinous substance, with a slight tint of brown. It is sometimes opaque, and sometimes almost perfectly transparent. When heated it melts like other resins; but it differs from them in not being soluble in alcohol, nor in oil of turpentine without peculiar management. Neither does it dissolve in the fixed oils with the same ease as the other resins. It resembles gum animé a little in appearance; but is easily distinguished by the solubility of this last in alcohol, and by its being brittle between the teeth, whereas animé softens in the mouth. The specific gravity of copal varies, according to Brisson, from 1·045 to 1·139. Mr Hatchett found it soluble in alkalies and nitric acid with the usual phenomena; so that in this respect it agrees with the other resins. The solution of copal in alkalies he found indeed opalescent, but it is nevertheless permanent. It deserves attention, that he found rosin, when dissolved in nitric acid, and then thrown down by an alkali, to acquire a smell resembling that of copal.

When copal is dissolved in any volatile liquid, and spread thin upon wood, metal, paper, &c. so that the volatile menstruum may evaporate, the copal remains perfectly transparent, and forms one of the most beautiful and perfect varnishes that can well be conceived. The varnish thus formed is called *copal varnish*, from the chief ingredient in it. This varnish was first discovered in France, and was long known by the name of *vernis martin*. The method of preparing it is concealed; but different processes for dissolving copal in volatile menstrua have been from time to time made public.

10. *Lac.*—This is a substance deposited on different species of trees in the East Indies, by an insect called *chermes lacca,* constituting a kind of comb or nidus. It has been imported into Europe, and extensively used from time immemorial; but it is only of late years that correct information concerning it has been obtained. For what relates to the natural history of the insect, and the mode of forming the lac, we are indebted to Mr Ker, Mr Saunders and Dr Roxburgh. Though very often employed in the arts, it was neglected by chemists. Mr Hatchett has lately examined it with his usual address, and ascertained its composition and properties.

There are various kinds of lac distinguished in commerce. *Stick lac* is the substance in its natural state, encrusting small twigs. When broken off and boiled in water it loses its red colour, and is called *seed lac.* When melted and reduced to the state of thin crust, it is called *shell lac.* Stick lac is of a deep red colour, and yields to water a substance which is used as a red dye. The other two varieties are brown.

Water dissolves the greatest part of the colouring matter of lac, which varies from 15 to ½ per cent. Alcohol dissolves the greatest part of the resin, which constitutes the chief ingredient in the composition of lac. Ether acts more feebly. Sulphuric acid dissolves and gradually chars lac; nitric acid dissolves, and then produces the same changes on it as on other resinous bodies. Muriatic and acetic acids likewise act as solvents. A solution of borax in water readily dissolves lac. The best proportions are 20 grains of borax, 100 grains of lac, and four ounces of water. This solution, mixed with lamp black, constitutes Indian ink; and may indeed be employed for many of the purposes of varnish. The fixed alkalies readily dissolve lac, but not the volatile. When placed on a hot iron it melts, and emits a thick smoke with an odour rather pleasant, leaving a spongy coal. When distilled, it yields water slightly acidulous, and a thick butyraceous oil. The gasses emitted are a mixture of carbonic acid and carbureted hydrogen. Stick lac yields also some carbonate of ammonia; but the other two varieties none. The following Table exhibits the constituents of the different varieties of lac, according to the analysis of Mr Hatchett.

	Stick Lac.	*Seed Lac.*	*Shell Lac.*
Resin	68	88·5	90·9
Colouring matter	10	2·5	0·5
Wax	6	4·5	4·0
Gluten	5·5	2·0	2·8
Foreign bodies	6·5		
Loss	4·0	2·5	1·8
	100	100	100

The resin is less brittle than those bodies usually are. The colouring matter possesses the properties of extractive; the wax is analogous to myrtle wax, and the gluten closely resembles the gluten of wheat.

11. *Amber.*—This substance is undoubtedly of vegetable origin; and though it differs from resins in some of its properties, yet it agrees with them in so many others, that it may, without impropriety, be referred to them.

Amber is a brittle, light, hard substance, usually nearly transparent; sometimes nearly colourless, but commonly yellow or even deep brown. It has considerable lustre. Its specific gravity is 1·065. It is tasteless, and without smell, except when pounded or heated, when it emits a fragrant odour. When heated it softens; but, as far as is known, cannot be melted without losing some of its weight, and altering its appearance. In a strong heat it burns, leaving a small quantity of ashes, the nature of which has not yet been ascertained. Water has no action on it; but alcohol, by long digestion, dissolves about one eighth of the amber, and forms a coloured solution, which when concentrated becomes milky when mixed with water. The residuum of the amber is not acted on by alcohol. Though amber be roasted before the action of the alcohol, the tincture is still formed. Hence we learn that the resinous part of amber is not expelled by a melting heat.

The weaker acids have no action on amber. Sulphuric acid converts it into a black resinous mass. Nitric acid acts upon it; when assisted by heat, nitrous gas is emitted.

Neither fixed nor volatile oils have any action on amber unless it has been previously roasted or exposed to a melting heat. When thus treated, it combines with oils, and the solution forms *amber varnish*. The process recommended by Nystrom is this: Amber is to be spread on a flat-bottomed iron pan, and placed on an equal coal fire till it melt; it is then to be withdrawn, covered with a plate of copper and iron, and allowed to cool. If the process be properly conducted, the amber will have lost half of its weight. If the fire be too strong, the amber will be scorched and rendered useless. If it be too low, the amber will not melt, but be reduced to a brown crust, which answers well enough for a varnish, provided it be exposed to heat till it is reduced to one half of the original weight. One part of this roasted amber is to be mixed with three parts of the linseed oil (rendered drying by litharge and white vitriol), and the mixture exposed to a gentle heat till the amber is dissolved: it is then to be withdrawn from the fire, and when nearly cold four parts of oil of turpentine are to be added. The whole is then allowed to settle, and the clear portion is passed through a linen cloth.

CHAP. XXIV.

OF GUAIACUM.

This substance is obtained from the *guaiacum officinale*, a tree which is a native of the West Indies, and yields a very hard heavy wood. The resin exudes spontaneously, and is also driven out artificially by heating one end of the wood in billets previously bored longitudinally; the melted resin runs out at the extremity farthest from the fire. This substance has been used in medicine for a considerable time, having been originally recommended in venereal diseases. Nothing is known concerning its original introduction into Europe.

It was considered by chemists as a resin, till Mr Hatchett observed, that when treated with nitric acid it yielded products very different from those of the resinous bodies. This induced Mr William Brande to examine its chemical properties in detail.

Guaiacum is a solid substance, resembling a resin in appearance. Its colour differs considerably, being partly brownish, partly reddish, and partly greenish; and it always becomes green when left exposed to the light in the open air. It has a certain degree of transparency, and breaks with a vitreous fracture. When pounded it emits a pleasant balsamic smell, but has scarcely any taste, although when swallowed it excites a burning sensation in the throat. When heated it melts, and diffuses at the same time a pretty strong fragrant odour. Its specific gravity is 1·2289.

When guaiacum is digested in water a portion of it is dissolved, the water acquiring a greenish brown colour and a sweetish taste. The liquid, when evaporated, leaves a brown substance which possesses the property of *extractive*.

Alcohol dissolves guaiacum with facility, and forms a deep brown coloured solution. Water renders this solution milky by separating the resin. Muriatic acid throws down the guaiacum of an ash grey, and sulphuric acid of a pale green colour. Acetic acid and the alkalies occasion no precipitate. Liquid oxymuriatic acid throws it down of a fine pale blue, which does not change when dried. Diluted nitric acid occasions no change at first; but after some hours the liquid becomes green, then blue, and at last brown, and at that period a brown coloured precipitate falls down. If water be mixed with the liquid when it has assumed a green or a blue colour, green and blue precipitates may be respectively obtained.

Sulphuric ether does not act so powerfully on guaiacum as alcohol. The solution obtained by means of it, exhibits the same properties when treated with re-agents as that in alcohol.

The alkaline solutions, both pure and in the state of carbonates, dissolve guaiacum with facility. Two ounces of a staturated solution of potash dissolved about 65 grains of guaiacum; the same quantity of ammonia only 25 grains; or guaiacum dissolves in about 15 parts of potash and 35 parts of ammonia.

Most of the acids act upon guaiacum with considerable energy.

Sulphuric acid dissolves it, and forms a deep red liquid, which deposites while fresh a lilac-coloured precipitate when mixed with water. When heat is applied the guaiacum is charred.

Nitric acid dissolves guaiacum completely without the assistance of heat, and with a strong effervescence. When the solution is evaporated, it yields a very large quantity of oxalic acid. No artificial tannin appears to be formed, but rather a substance possessing the properties of extractive. Diluted nitric acid converts guaiacum into a brown substance, similar to the precipitate obtained by nitric acid from the the alcoholic solution of guaiacum. This brown matter possesses the properties of a resin.

Muriatic acid acts but slightly, as the guaiacum soon melts into a blackish mass, which is not acted upon.

When guaiacum is distilled, 100 parts of it yielded to Mr Brande the following products:

Acidulous water	5·5
Thick brown oil	24·5
Thin empyreumatic oil	30·0
Charcoal	30·5
Gasses, consisting of carbonic acid and carbureted hydrogen	9·5
	100·0

The coal when incinerated left three grains of lime, but no alkaline substance.

CHAP. XXV.

OF BALSAMS.

The term *balsam* or *balm* was originally confined to a thick fragrant juice obtained from the *amyris gileadensis*, and afterwards applied by chemists to all substances which possess the same degree of consistence and a strong smell, whether natural or artificial. Bucquet restricted the term to those resinous-like substances which yield benzoic acid when heated. This new meaning of the word, which has been adopted by chemists in general, has introduced into the class of balsams several substances which were formerly considered as resins. The word *balsam* originally implied a substance possessing a certain degree of fluidity; but now there are two classes of balsams; the one fluid, and the other solid and brittle.

A balsam, then, is a substance which possesses the general properties of a resin; but which, when heated or digested in acids, yields a portion of benzoic acid. Chemists, in general, have considered them as combinations of a resin with benzoic acid; but Mr Hatchett has made it probable, that the acid is formed at the time of its separation.

They are insoluble in water; but when boiled in that liquid often give out a portion of benzoic acid. Alcohol and ether dissolve them readily. The strong acids likewise dissolve them; and during the solution a portion of benzoic acid is separated. Nitric acid, in some cases, evolves likewise traces of prussic acid. The alkalies act upon them nearly as on the resins. They may be divided into two classes; namely, *liquid* and *solid* balsams.

1. *Liquid Balsams.*

The liquid balsams at present known are four in number; namely,

1. Copaiva
2. Tolu
3. Peru
4. Styrax.

1. *Copaiva.*—This balsam is obtained from the *copaifera officinalis;* a tree which grows in South America, and some of the West India islands. It exudes from incisions made in the trunk of the tree. The juice thus obtained is transparent, of a yellowish colour, an agreeable smell, a pungent taste, at first of the consistence of oil, but it gradually becomes as thick as honey. Its specific gravity is 0·950. When

mixed with water and distilled, there comes over with the water a very large quantity of volatile oil. The residuum consists of two substances; namely, the watery portion, and a greyish yellow substance, lying at the bottom of the vessel, which, on exposure to the air, dries, and becomes brittle and transparent. When heated it melts, and possesses the characters of a resin. When distilled it yielded a yellowish thick oil, some acidulous thick water, and a gas; one-sixth of which was carbonic acid, and the remainder seemed to possess the characters of olefiant gas. From these facts, which have been long known, it was concluded, that copaiva is a compound of a resin and a volatile oil, which passes over at a heat inferior to that of boiling water; but the experiments of Schonberg have rendered it much more probable, that the balsam is decomposed when distilled along with water, and that both the oil and resin are new products.

Whether this balsam yields benzoic acid has not been ascertained. Its properties are rather against the probability of its doing so. Indeed it bears a striking resemblance to turpentine in many respects; and ought, along with it, to constitute a class of bodies intermediate between volatile oils and resins, to which the name of *turpentines* might be given.

Balsam of Tolu.—This substance is obtained from the *toluifera balsamum,* a tree which grows in South America. The balsam flows from incisions made in the bark. It comes to Europe in small gourd shells. It is of a reddish brown colour and considerable consistence; and when exposed to the air, it becomes solid and brittle. Its smell is fragrant, and continues so even after the balsam has become thick by age. When distilled with water, it yields very little volatile oil, but impregnates the water strongly with its taste and smell. A quantity of benzoic acid sublimes, if the disillation be continued.

Balsam of Peru.—This substance is obtained from the *myroxylon peruiferum*, which grows in the warm parts of South America. The tree is full of resin, and the balsam is obtained by boiling the twigs in water. It has the consistency of honey, a brown colour, an agreeable smell, and a hot acrid taste. When boiled with water for some time, the liquid separated by the filter reddens vegetable blues, and deposits crystals of benzoic acid on cooling. The water contains no other substance. When distilled with water, it yields a very small quantity of reddish limpid oil.

4. *Styrax.*—This is a semifluid juice, said to be obtained from the *liquidambar styraciflua*, a tree which grows in Virginia, Mexico, and some other parts of America. It is prepared according to Mr Petiver, in the island of Cobross in the Red Sea, from the bark of a tree called *rosa mallos* by the natives, and considered by botanists as the same with the American species. The bark of this tree is boiled in salt water to the consistence of bird-lime, and then put into casks. Its colour is greenish, its taste aromatic, and its smell agreeable. It is easily volatilized by heat. When treated with water, benzoic acid is dissolved. It is totally soluble in alcohol except the impurities. When exposed to the air it becomes harder, and absorbs oxygen. When distilled, it yields an acidulous water, having the odour of benzoic acid, a limpid colourless hot oil, a solid coloured oil, benzoic acid, and a mixture of carbonic acid and carbureted hydrogen. The charcoal is light, and contains some oil.

2. *Solid Balsams.*

The solid balsams at present known are only three in number; namely,

1. Benzoin
2. Storax
3. Dragon's blood.

1. *Benzoin.*—This substance is the produce of the *styrax benzoe*, a tree which grows in Sumatra, &c. Benzoin is obtained from this tree by incision; a tree yielding three or four pounds. It is a solid brittle substance, sometimes in the form of yellowish white tears joined together by a brown substance, and sometimes in the form of a brown substance not unlike common rosin. It has a very agreeable smell, which is increased by heating the benzoin. It has little taste. Its specific gravity is 1·092.

Cold water has very little effect on benzoin, but boiling water takes up a portion of benzoic acid.

Alcohol dissolves it when assisted by a gentle heat, and forms a deep yellow solution inclining to reddish brown. When this solution is diluted with water, the benzoin precipitates in the form of a white powder.

Ether dissolves benzoin with facility, and the solution with re-agents exhibits the same phenomena as the alcoholic.

Nitric acid acts with violence on benzoin, and converts it into an orange-coloured mass. When assisted by heat, the acid dissolves the benzoin; and as the solution cools, crystals of benzoic acid gradually separate.

Sulphuric acid dissolves benzoin, while benzoic acid sublimes; the solution is at first a deep red. By continuing the digestion, a portion of artificial tannin is formed, and the charcoal evolved amounts to 0·48 of the benzoin dissolved.

Acetic acid dissolves benzoin without the assistance of heat. When heat is applied, the solution, as it cools, becomes turbid; owing to the separation of benzoic acid.

Benzoin is dissolved by a boiling lixivium of the fixed alkalies; a dark brown solution is formed, which becomes turbid after some days exposure to the air. Ammonia likewise dissolves benzoin sparingly.

When Mr Brande exposed 100 grains of benzoin in a retort to a heat gradually raised to redness, the products were,

Benzoic acid	9·0
Acidulous water	5·5
Butyraceous and empyreumatic oil	60·0
Charcoal	22·0
Carbureted hydrogen and carbonic acid	3·5
	100·0

2. *Storax.*—This is the most fragrant of all the balsams, and is obtained from the *styrax officinalis*, a tree, which grows in the Levant, and it is said also in Italy.* Sometimes it is in the state of red tears; and this is said to be the state in which it is obtained from the tree. But common storax is in large cakes; brittle, but soft to the touch, and of a reddish brown colour. This is more fragrant than the other sort, though it contains a considerable mixture of saw-dust. It dissolves in alcohol. When distilled with alcohol or with water, scarcely any oil is obtained. When distilled by the naked fire, it seems from the experiments of Neumann, to yield the same products as benzoin.

3. *Dragon's blood.*—This is a brittle substance of a dark red colour, which comes from the East Indies. There are two sorts of it; one in small oval drops or tears of a fine deep red, which becomes crimson when the tears are reduced to powder; the other is in larger masses, some of which are pale red, and others dark. It is probably obtained from different kinds of trees; the *calamus draco* is said to furnish most of what comes from India. The *dracæna draco* and the *pterocarpus draco* are also said to furnish it.

Dragon's blood is brittle and tasteless, and has no sensible smell. Water does not act upon it, but alcohol dissolves the greatest part, leaving a whitish red substance, partially acted upon by water. The solution has a fine deep red colour, which stains marble, and the stain penetrates the deeper the hotter the marble is. It dissolves also in oils, and gives them a deep red colour. When heated it melts, catches flame, and emits an acid fume similar to that of benzoic acid. When digested with lime, a portion of it becomes soluble in water, and it acquires a balsamic odour. On adding muriatic acid to the solution, a red resinous substance is precipitated, and slight traces of benzoic acid only become perceptible. Nitric acid acts upon it with energy, changes it to a deep yellow, a portion of benzoic acid is sublimed, and a brown mass remains soluble in water, and possessing the properties of artificial tannin.

CHAP. XXVI.

OF CAOUTCHOUC.

About the beginning of the 18th century, a substance called *caoutchouc* was brought as a curiosity from America. It was soft, wonderfully elastic, and very combustible. The pieces of it that came to Europe were usually in the shape of bottles, birds, &c. This substance is very much used in rubbing out the marks made upon paper by a black lead pencil; and therefore in this country it is often called *Indian rubber*.

It is now known that there are at least two trees in South America from which caoutchouc may be obtained; the *hævea caoutchouc*, and the *jatropha elastica*; and it is exceedingly probable that it is extracted also from other species of *hævea* and *jatropha*. Several trees likewise which grow in the East Indies yield caoutchouc; the principal of these are, e *ficus indica*, the *artocarpus integrifolia*, and the *urceola* *astica*.

When any of these plants are punctured, there exudes from a milky juice, which, when exposed to the air, gradually ts fall a concrete substance, which is caoutchouc.

If oxymuriatic acid be poured into the milky juice, the outchouc precipitates immediately, and at the same time e acid loses its peculiar odour. This renders it probable at the formation of the caoutchouc is owing to its basis abrbing oxygen. If the milky juice be confined in a glass ssel containing common air, it gradually absorbs oxygen, d a pellicle of caoutchouc appears on its surface.

Caoutchouc, when pure, is of a white colour, and without ther taste or smell. The blackish colour of the caouthouc of commerce is owing to the method employed in dryg it after it has been spread upon moulds. The usual way to spread a thin coat of the milky juice upon the mould, nd then to dry it by exposing it to smoke; afterwards anoier coat is spread on, which is dried in the same way. Thus he caoutchouc of commerce consists of numerous layers of ure caoutchouc alternating with as many layers of soot.

Caoutchouc is soft and pliable like leather. It is exceedngly elastic and adhesive; so that it may be forcibly stretchd out much beyond its usual length, and instantly recover ts former bulk when the force is withdrawn. It cannot be roken without very considerable force. Its specific gravity 0.9335.

Caoutchouc is not altered by exposure to the air; it is perectly insoluble in water: but if boiled for some time its edges ecome somewhat transparent, owing undoubtedly to the waer carrying off the soot; and so soft, that when two of them re pressed and kept together for some time, they adhere as losely as if they formed one piece. By this contrivance pieces of caoutchouc may be soldered together, and thus made to assume whatever shape we please.

Caoutchouc is insoluble in alcohol. This property was discovered very early, and fully confirmed by the experiments of Mr Macquer. The alcohol, however, renders it colourless.

Caoutchouc is soluble in ether. This property was first pointed out by Macquer. Berniard, on the contrary, found that caoutchouc was scarcely soluble at all in sulphuric ether, which was the ether used by Macquer, and that even nitric ether was but an imperfect solvent. The difference in the results of these two chemists was very singular; both were remarkable for their accuracy, and both were too well acquainted with the subject to be easily misled. The matter was first cleared up by Mr Cavallo. He found that ether, when newly prepared, seldom or never dissolved caoutchouc completely; but if the precaution was taken to wash the ether previously in water, it afterwards dissolved caoutchouc with facility.

When the ether is evaporated, the caoutchouc is obtained unaltered. Caoutchouc, therefore, dissolved in ether, may be employed to make instruments of different kinds, just as the milky juice of the *hævea;* but this method would be a great deal too expensive for common use.

Caoutchouc is soluble in volatile oils; but, in general, when these oils are evaporated, it remains somewhat glutinous, and therefore is scarcely proper for those uses to which, before its solution, it was so admirably adapted.

The acids act but feebly upon caoutchouc. Sulphuric acid, even after a long digestion, only chars it superficially. When treated with nitric acid, there came over azotic gas, carbonic acid gas, prussic acid gas; and oxalic acid is said to be formed. Muriatic acid does not affect it. The other acids have not been tried.

Fabroni has discovered, that rectified petroleum dissolves it, and leaves it unaltered when evaporated.

When exposed to heat it readily melts; but it never afterwards recovers its properties, but continues always of the consistence of tar. It burns very readily with a bright flame, and diffuses a fetid odour. In those countries where it is produced, it is often used by way of candle.

When distilled it gives out ammonia. It is evident from this, and from the effect of sulphuric and nitric acid upon it, that it is composed of carbon, hydrogen, azote, and oxygen; but the manner in which they are combined is unknown.

CHAP. XXVII.

OF GUM RESINS.

This class of vegetable substances has been long distinguished by physicians and apothecaries It contains many active substances much employed in medicine; and they certainly possess a sufficient number of peculiar properties to entitle them to be ranked apart. Unfortunately these substances have not yet attracted much of the attention of chemists. Their properties and constituents of course are but imperfectly ascertained.

They are usually opaque, or at least their transparency is inferior to that of the resins. They are always solid, and most commonly brittle, and have sometimes a fatty appearance.

When heated they do not melt as the resins do; neither are they so combustible. Heat, however, commonly softens them, and causes them to swell. They burn with a flame.

They have almost always a strong smell, which in several instances is alliaceous. Their taste also is often acrid, and always much stronger than that of the resins.

They are partially soluble in water; but the solution is always opaque, and usually milky.

Alcohol dissolves only a portion of them. The solution is transparent; but when diluted with water it becomes milky; yet no precipitate falls, nor is any thing obtained by filtering the solution.

Vinegar and wine likewise dissolve them partially; and the solution, like the aqueous, is opaque or milky.

According to Hermbstadt, they are insoluble in sulphuric ether.

The action of alkalies on them has been examined only by Mr Hatchett. All of them tried by that celebrated chemist dissolved readily in alkaline solutions when assisted by heat. We may therefore consider them as soluble in alkalies like resins.

Nitric acid acts upon them with energy; converting them first into a brittle mass, and then, with the assistance of heat, dissolving them.

Their specific gravity is usually greater than that of the resins.

Their other properties still continue unknown. They all either exude spontaneously from plants, or are obtained by incisions. At first they seem to be in a liquid state; but they gradually harden when exposed to the air and weather.

The gum resins which have been hitherto applied to any useful purpose are the following:—

1. *Galbanum.* It is obtained from the *bubon galbanum*, a perennial plant, and a native of Africa. When this plant is cut across a little above the root, a milky juice flows out, which soon hardens and constitutes galbanum. It comes to this country from the Levant, in small pieces composed of tears, agglutinated together, of a yellowish or white colour.

Its taste is acrid and bitter, and its smell peculiar. Water, vinegar, and wine, dissolve part of it, but the solution is milky. Alcohol dissolves about three-fifths.

2. *Ammoniac.*—This substance is brought from the East Indies. Nothing certain is known concerning the plant which yields it; though from analogy it has been suspected to be a species of *ferula*. It is in small pieces agglutinated together, and has a yellowish white colour. Its smell is somewhat like that of galbanum, but more pleasant. Its taste is a nauseous sweet mixed with bitter. It does not melt. Water dissolves a portion of it; the solution is milky, but gradually lets fall a resinous portion. More than one-half is soluble in alcohol. This portion is a resin.

According to the analysis of Braconnot ammoniac is composed of the following ingredients:

70·0	resin
18·4	gum
4·4	glutinous matter
6·0	water
1·2	loss
100·0	

3. *Olibanum*—This substance is obtained from the *juniperus lycia*, and is chiefly collected in Arabia. It is the frankincense of the ancients. It is in transparent brittle masses about the size of a chesnut. Its colour is yellow. It has a bitterish nauseous taste; and when burnt diffuses an agreeable odour. Alcohol dissolves three-fourths of it; and water about three-eighths.

4. *Asafœtida.*—This substance is obtained from the *ferula asafœtida*, a perennial plant which is a native of Persia. When the plant is about four years old, its roots are dug up and cleaned. Their extremity being then cut off, a milky juice exudes, which is collected. Then another portion is

cut off, and more juice exudes. This is continued till the roots are exhausted. The juice thus collected soon hardens and constitutes *asafœtida*. It comes to Europe in small grains of different colours, whitish, reddish, violet, brown. Pretty hard, but brittle. Its taste is acrid and bitter; its smell strongly allicaceous and fetid. Alcohol dissolves about three-fourths of this substance; and water takes up nearly one-fourth if applied before the spirit.

5. *Scammony*.—This substance is obtained from the *convolvulus scammonia*, a climbing plant which grows in Syria. The roots when cut yield a milky juice. This when collected and allowed to harden constitutes scammony. Colour dark grey or black. Smell peculiar and nauseous: taste bitter and acrid. With water it forms a greenish-coloured opaque liquid. Alcohol dissolves the greatest part of it. It is usually mixed with the expressed juice of the root, and frequently also with other impurities, which alter its appearance. In medicine it operates as a strong cathartic.

6. *Opoponax*.—This substance is obtained from the *pastinaca opoponax*, a plant which is a native of the countries round the Levant. The gum resin, like most others, is obtained by wounding the roots of the plant. The milky juice, when dried in the sun, constitutes the opoponax. It is in lumps of a reddish yellow colour, and white within. Smell peculiar. Taste bitter and acrid. With water it forms a milky solution, and about one-half of it dissolves. Alcohol acts but feebly.

7. *Gamboge* or *Gumgutt*.—This substance is obtained from the *stalagmitis gambogioides*, a tree which grows wild in the East Indies. In Siam it is obtained in drops by wounding the shoots; in Ceylon it exudes from wounds in the bark. It is brought to Europe in large cakes. Its colour is yellow; it is opaque, brittle, and breaks vitreous. It has no smell, and very little taste. With water it forms

a yellow turbid liquid. Alcohol dissolves it almost completely; and when mixed with water becomes turbid, unle the solution contains ammonia.

Braconnet analysed it, and found it composed of one part of a gum which possessed the properties of cherry tree gum, and four parts of a reddish brittle resin which possessed the characteristic properties of the resins.

8. *Myrrh.*—The plant from which this substance is obtained is unknown. If we believe Bruce it belongs to the genus of *mimosa*. It grows in Abyssinia and Arabia. It is in the form of tears. Colour reddish yellow; when pure somewhat transparent, but it is often opaque. Odour peculiar. Taste bitter and aromatic. Does not melt when heated, and burns with difficulty.

From the analysis of Braconnot it appears that myrrh is composed of about

23 resin
77 gum
———
100

The resin is reddish, has a bitter taste and the peculiar odour of myrrh. The gum differs in its properties from every other gummy substance hitherto examined. It has a dark brown colour; is at first soluble in water, but by boiling the liquid, or by exposing the gum to heat, it requires cohesive properties, and becomes insoluble in water. When distilled it yields ammonia, and when dissolved in nitric acid, azotic gas is disengaged.

It deserves attention, that the gum resins, when subjected to destructive distillation, yield all of them a portion of ammonia; a proof that they all contain azote. In this respect they agree with gum and extractive.

CHAP. XXVIII.

OF COTTON.

Cotton is a soft down which envelopes the seeds of various plants, especially the different species of *gossypium*, from which the cotton of commerce is procured. These plants are natives of warm climates; grow wild in Asia, Africa, and America, within the tropics; and are cultivated in the East and West Indies.

Though no correct chemical investigation of the properties of cotton has hitherto been made, yet as its obvious qualities distinguish it sufficiently from every other vegetable substance, we must consider it as a peculiar vegetable principle; and I have introduced it here, in hopes that some person or other will be induced to examine its nature in detail. The following are the particulars at present known.

This substance is in threads differing in length and fineness. No asperities can be discovered on the surface of these threads; but if Lewenhoeck's microscopical observations are to be trusted, they are all triangular, and have three sharp edges. Cotton differs considerably in colour; but when *bleached* it becomes of a fine white.

Cotton is tasteless and destitute of smell. It is completely insoluble in water, alcohol, ether, and oils, and in all the vegetable acids.

The diluted alkaline leys have no perceptible action on cotton; but when very strong they dissolve it if assisted by a sufficient degree of heat. The new products obtained by this solution have not been examined.

Cotton combines readily with tannin, and forms a yellow or brown compound. Hence the infusion of galls, and other astringent substances, is often used as a mordant for cotton.

Nitric acid decomposes cotton when assisted by heat, and oxalic acid is formed; the other products have not been examined. Sulphuric acid likewise chars it. Oxymuriatic acid gas bleaches it, and probably alters and dissolves it when applied in a concentrated state.

Cotton is extremely combustible, and burns with a clear lively flame. The ashes left behind, according to Neumann, contain some potash. When distilled it yields a great portion of acidulous water, and a small quantity of oil, but no ammonia.

CHAPTER XXIX.

OF SUBER.

This name has been introduced into chemistry by Fourcroy, to denote the outer bark of the *quercus suber*, or the common cork; a substance which possesses properties different from all other vegetable bodies.

It is exceedingly light, soft, and elastic; very combustible, burning with a bright white flame, and leaving a light black bulky charcoal; and when distilled, it yields a little ammonia.

When digested in water, a yellowish-coloured solution is obtained, seemingly containing extractive, as nearly the same proportion is taken up by alcohol. Sulphuric acid readily chars it. Nitric acid gives it a yellow colour, corrodes, dissolves, and decomposes it; converting it partly into suberic acid, partly into a substance resembling wax, partly into artificial tannin, and partly into a kind of starchy matter.

CHAP. XXX.

OF WOOD.

All trees, and most other plants, contain a particular substance well known by the name of *wood.* If a piece of wood be well dried, and digested, first in a sufficient quantity of water and then of alcohol, to extract from it all the substances soluble in these liquids, there remains only behind the *woody fibre.*

This substance, which constitutes the basis of wood, is composed of longitudinal fibres, is easily subdivided into a number of smaller fibres. It is somewhat transparent; is perfecty tasteless; has no smell; and is not altered by exposure to the atmosphere.

It is insoluble in water and in alcohol. The fixed alkalies, when assisted by heat, give it a deep brown colour, render it soft, and decompose it. A weak alkaline solution dissolves it without alteration; and it may be thrown down again by means of an acid. By this property we are enabled to separate wood from most of the other vegetable principles, as few of them are soluble in weak alkaline leys.

When heated, it blackens without melting or frothing up, and exhales a disagreeable acrid fume, and leaves a charcoal which retains exactly the form of the original mass. When distilled in a retort, it yields an acid liquor of a peculiar taste and smell, distinguished by the name of pyroligneous, and formerly considered as a distinct acid; but Fourcroy and Vauquelin have lately ascertained that it is merely the acetic acid combined with an empyreumatic oil.

CHAP. XXXI.

OF ALKALIES.

The only alkalies found in plants are potash and soda. Ammonia may indeed be obtained by distilling many vegetable substances, but it is produced during the operation. One or other of these alkalies is found in every plant which has hitherto been examined. The quantity indeed is usually very small. From the experiments of Vauquelin, it is probable that the alkalies are combined in plants with acetic and carbonic acids.

1. Potash is found in almost all plants which grow at a distance from the sea. It may be extracted by burning the vegetable, washing the ashes in water, filtrating the water, and evaporating it to dryness. It is in this manner that all the potash of commerce is procured.

In general, three times as much ashes are obtained from shrubs, and five times as much from herbs, as from trees. Equal weights of the branches of trees produce more ashes than the trunk, and the leaves more than the branches. Herbs arrived at maturity produce more ashes than at any other time. Green vegetables produce more ashes than dry.

2. Soda is found in almost all the plants which grow in the sea, and in many of those which grow on the shore. In general, the quantity of soda which plants contain bears a much greater proportion to their weight than the potash does which is found in inland vegetables. 100 parts of the *salsola soda*, for instance, yield 19·921 of ashes; and these contain 1·992 parts of soda; some of which, however, is combined with muriatic acid. The plants from which the greater part of

the soda, or *barilha* as it is called, which is imported from Spain, is extracted, are the *salsola sativa* and *vermiculata.*

CHAP. XXXII.

EARTHS.

The only earths hitherto found in plants are the four following: *lime, silica, magnesia, alumina.*

1. Lime is usually the most abundant of the earths of plants, and the most generally diffused over the vegetable kingdom. Indeed it is a very uncommon thing to find a plant entirely destitute of lime: salsola soda is almost the only one in which we know for certain that this earth does not exist.

2. Silica exists also in many plants, particularly in grasses and equisetums. Mr Davy has ascertained that it forms a part of the epidermis, or outer bark of these plants; and that in some of them almost the whole epidermis is silica.

3. Magnesia does not exist so generally in the vegetable kingdom as the two preceding earths. It has been found, however, in considerable quantities in several sea plants, especially fuci; but the salsola soda contains a greater proportion of magnesia than any plant hitherto examined. Mr Vauquelin found that 100 parts of it contained 17·929 of that earth.

4. Alumina has only been found in very small quantities in plants.

The following table exhibits the quantity of earths and metallic oxides in grains, obtained by Schræder from 32 ounces of the seeds of the following kinds of corn; wheat *(triticum hybernum)*, rye *(secale cereale)*, barley *(hordeum* *vulgare)*, oats *(avena sativa)*, and likewise from the same quantity of rye straw.

	Wheat.	*Rye.*	*Barley.*	*Oats.*	*Rye Straw.*
Silica	13·2	15·6	66.7	144·2	152
Carbonate of lime . .	12·6	13·4	24·8	33·75	46·2
Carbonate of magnesia	13·4	14·2	25·3	33·9	28·2
Alumina	0·6	1·4	4·2	4·5	3·2
Oxide of manganese .	5·0	3·2	6·7	6·95	6·8
Oxide of iron . . .	2·5	0·9	3·8	4·5	2·4
	47·3	48·7	131·5	227·8	328·8

CHAP. XXXIII.

OF METALS.

Several metallic substances have also been found in the ashes of vegetables, but their quantity is exceedingly small; so small, indeed, that without very delicate experiments their presence cannot even be detected.

The metals hitherto discovered are iron, which is by far the most common, manganese, and, if we believe some chemists, gold.

1. Iron has been found in many plants; the ashes of salsola contain a considerable quantity of it.

2. Scheele first detected manganese in vegetables. Proust found it in the ashes of the pine, calendula, vine, green oak, and fig-tree.

3. With respect to the minute portion of gold extracted from the ashes of plants by Kunkel, Sage, &c. it is probable that it proceeded rather from the lead which they employed in their processes than from the ashes.

DIVISION V.

OF ANIMAL SUBSTANCES.

When we compare animals and vegetables together, each in their most perfect state, nothing can be easier than to distinguish them. The plant is confined to a particular spot, and exhibits no mark of consciousness or intelligence; the animal, on the contrary, can remove at pleasure from one place to another, is possessed of consciousness, and a high degree of intelligence. But on approaching the contiguous extremities of the animal and vegetable kingdom, these striking differences gradually disappear, the objects acquire a greater degree of resemblance, and at last approach each other so nearly, that it is scarcely possible to decide whether some of those species which are situated on the very boundary belong to the animal or vegetable kingdom.

To draw a line of distinction, then, between animals and vegetables, would be a very difficult task: but it is not necessary at present to attempt it; for almost the only animals whose bodies have been hitherto examined with any degree of chemical accuracy, belong to the most perfect classes, and consequently are in no danger of being confounded with plants. Indeed, the greater number of facts which I have to relate apply only to the human body, and to those of a few domestic animals. The task of analysing all animal bodies is immense, and must be the work of ages of indefatigable industry.

This part of the subject naturally divides itself into two chapters. In the first chapter, I shall give an account of the different ingredients hitherto found in animals, such of them at least as have been examined with any degree of accuracy, and, in the second, I shall treat of the different members of which animal bodies are composed; which must consist each of various combinations of the ingredients described in the first chapter.

CHAP. I.

OF ANIMAL SUBSTANCES.

The substances which have been hitherto detected in the animal kingdom, and of which the different parts of animals, as far as these parts have been analysed, are found to be composed, may be arranged under the following heads:

1. Gelatine
2. Albumen
3. Mucus
4. Fibrin
5. Urea
6. Saccharine matter
7. Oils
8. Resins
9. Sulphur
10. Phosphorus
11. Acids
12. Alkalies
13. Earths
14. Metals,

These shall form the subject of the following sections.

SECT. I. *Of Gelatine.*

If a piece of the fresh skin of an animal, an ox, for instance, after the hair and every impurity is carefully separated, be washed repeatedly in cold water till the liquid ceases to be coloured, or to abstract any thing; if the skin, thus purified, be put into a quantity of pure water, and boiled for some time, part of it will be dissolved. Let the decoction be slowly evaporated till it is reduced to a small quantity, and then put aside to cool. When cold, it will be found to have assumed a solid form, and to resemble precisely that tremulous substance well known to every body under the name of *jelly*. This is the substance called in chemistry *gelatine*. If the evaporation be still farther continued, by exposing the jelly to dry air, it becomes hard, semitransparent, breaks with a glassy fracture, and is, in short, the substance so much employed in different arts under the name of *glue*. Gelatine, then, is precisely the same with glue; only that it must be supposed always free from those impurities with which glue is so often contaminated.

Gelatine is semitransparent and colourless when pure. Its consistency and hardness vary considerably. The best kinds are very hard, brittle, and break with a glassy fracture. Its taste is insipid, and it has no smell.

When thrown into water it swells very much, but does not readily dissolve; and when taken out, it is soft and gelatinous; but when allowed to dry, it recovers its former appearance. If it be put in this gelatinous state into warm water, it very soon dissolves, and forms a solution of an opal colour, and the more opaque according to the quantity of gelatine which it contains. Tremulous gelatine dissolves in a very small portion of hot water; but as the solution cools, it gelatinizes afresh. If this solution, as soon as it assumes the tremulous form, be mixed with cold water and shaken, a complete solution takes place.

Dry gelatine undergoes no change when kept; but in the gelatinous state, or when dissolved in water, it very soon putrefies; an acid makes its appearance in the first place (probably the acetic), a fetid odour is exhaled, and afterwards ammonia is formed.

Acids dissolve gelatine with facility, even when diluted, especially when assisted by heat; but we are still ignorant of the changes produced upon it by these agents except by nitric acid. When this acid is digested on it, a small quantity of azotic gas is disengaged, then abundance of nitrous gas; the gelatine is dissolved, except an oily matter which appears on the surface, and converted partly into oxalic and malic acids.

Alkalies dissolve gelatine with facility, especially when assisted by heat; but the solution does not possess the properties of soap.

None of the earths seem to combine with gelatine; at least they do not precipitate it from its solution in water.

The metals in their pure state have no effect upon gelatine; but several of the metallic oxides, when agitated in a solution of gelatine, have the property of depriving the water of the greatest part of that body, with which they form an insoluble compound. Several of the metallic salts likewise precipitate gelatine from water.

Gelatine is insoluble in alcohol. When alcohol is mixed with a solution of gelatine, the mixture becomes milky; but becomes again transparent when agitated, unless the solution be concentrated, and the quantity of alcohol considerable. Gelatine is most probably equally insoluble in ether; though I believe the experiment has not been tried.

When the solution of tannin is dropt into gelatine, a copious white precipitate appears, which soon forms an elastic adhesive mass not unlike vegetable gluten. This precipitate is composed of gelatine and tannin; it soon dries in the open air, and forms a brittle resinous-like substance, insoluble in water, capable of resisting the greater number of chemical agents, and not susceptible of putrefaction.

Gelatine, does not, properly speaking, combine with oils, but it renders them misciable with water, and forms a kind of emulsion.

From the effects of different re-agents on gelatine, and from the decomposition which it undergoes when heated, we see that it contains carbon, hydrogen, azote, and oxygen. But what the proportion of these constituents are, cannot be easily ascertained. The phosphate of lime, and the traces of soda, which it always yields, are most likely only held in solution by it.

SECT. II. *Of Albumen.*

The eggs of fowls contain two very different substances: a yellow oily-like matter, called the *yolk;* and a colourless glossy viscid liquid, distinguished by the name of *white.* This last is the substance which chemists have agreed to denominate *albumen.* The white of an egg, however, is not pure albumen. It contains also some mucus, soda, and sulphur: but as albumen is never found perfectly pure, and as no method is known of separating it without at the same time altering the properties of the albumen, chemists are obliged to examine it while in combination with these bodies.

Albumen dissolves readily in water, and the solution has the property of giving a green colour to vegetable blues, in consequence of the soda which it contains. When albumen is heated to the temperature of 165°, it *coagulates* into a white solid mass; the consistency of which, when other things are equal, depends, in some measure, on the time during which the heat was applied. The coagulated mass has precisely the same weight that it had while fluid. This property of coagulating when heated is characteristic of albumen, and distinguishes it from other bodies.

The taste of coagulated albumen is quite different from that of liquid albumen: its appearance, too, and its properties, are entirely changed; for it is no longer soluble, as before, either in hot or in cold water.

The coagulation of albumen takes place even though air be completely excluded; and even when air is present, there is no absorption of it, nor does albumen in coagulating change its volume. Acids have the property of coagulating albumen, as Scheele ascertained. Alcohol also produces, in some measure, the same effect. *Heat*, then, *acids* and *alcohol*, are the agents which may be employed to coagulate albumen.

It is remarkable, that if albumen be diluted with a sufficient quantity of water, it can no longer be coagulated by any of these agents.

We see, therefore, that albumen ceases to coagulate whenever its particles are separated from each other beyond a certain distance. That no other change is produced, appears evident from this circumstance, that whenever the watery solution of albumen is sufficiently concentrated by evaporation, coagulation takes place, upon the application of the proper agents, precisely as formerly.

It does not appear that the distance of the particles of albumen is changed by coagulation; for coagulated albumen occupies precisely the same sensible space as liquid albumen.

Albumen, then, is capable of existing in two states; the one before it has been coagulated, and the other after it has undergone coagulation. Its properties are very different in each. It will be proper therefore to consider them separately.

Albumen in its natural state, or uncoagulated, is a glary liquid, having little taste and no smell. When dried spontaneously, or in a low heat, it becomes a brittle transparent glassy like substance; which, when spread thin upon surfaces, forms a varnish, and is accordingly employed by bookbinders for that purpose. When thus dried it has a considerable resemblance to gum arabic, to which also its taste is similar. The white of an egg loses about four-fifths of its weight in drying. It is still soluble in water, and forms the same glary liquid as before.

From the experiments of Dr Bostock, it appears, that when one part of this dry albumen is dissolved in nine parts of water, the solution becomes perfectly solid when coagulated by heat; but if the albumen amounts only to $\frac{1}{13}$th of the liquid, then, though coagulation takes place, the liquid does not become perfectly solid, but may be poured from one vessel to another.

When one grain of albumen is dissolved in 1000 grains of water, the solution becomes cloudy when heated.

Uncoagulated albumen soon putrefies unless it be dried; in which state it does not undergo any change. It putrefies more readily when dissolved in a large quantity of water than when concentrated. The smell of white of egg, allowed to run into putrefaction, resembles that of *pus*.

It is insoluble in alcohol and ether, which immediately coagulate it, unless it be mixed with a very great proportion of water; in which case even acids have no effect.

When acids are poured upon it, coagulation takes place equally; but several of them have the property of dissolving it again when assisted by heat. This at least is the case with sulphuric acid. The solution is of a green colour, and does not soon blacken even when boiled. It is the case also with nitric acid, and probably also with muriatic acid. Nitric acid first disengages some azotic gas; then the albumen is gradually dissolved, nitrous gas emitted, oxalic and malic acids formed, and a thick oily matter makes its appearance on the surface.

None of the earths form insoluble compounds, with albumen; in this respect they resemble the alkalies. The case is different with the metallic oxides.

Every metal tried, except cobalt, occasions a precipitate; but no precipitate ever appears when the oxide is held in solution by an alkali or earth. The effect of the metallic salts on albumen forms a striking contrast with their effect on gelatine.

From the experiments of Dr Bostock, it appears that a drop of the saturated solution of oxymuriate of mercury, let fall into water containing $\frac{1}{1000}$th part of its weight of albumen, produces an evident milkiness, and a curdy precipitate falls. It is therefore a very delicate test of the presence of albumen in animal fluids.

If a solution of tannin be poured into an aqueous solution of uncoagulated albumen, it forms with it a very copious yellow precipitate of the consistence of pitch, and insoluble in water. This precipitate is a combination of tannin and albumen. When dry it is brittle, like over-tanned leather, and is not susceptible of putrefaction. This property which albumen has of precipitating with tannin was discovered by Seguin.

The infusion af galls is by no means so delicate a test of the presence of albumen as of gelatine. When an infusion of galls containing $2\frac{1}{2}$ *per cent*. of solid matter, and water holding $\frac{1}{1000}$th of albumen in solution, are mixed in equal quantities, no effect is produced at first, but after some time a precipitating matter appears and slowly subsides.

II. When albumen is coagulated either by heat, alcohol, or acids, it is an opaque substance of a pearl white colour, tough, and of a sweetish mucilaginous taste. It is no longer soluble in water, and is not nearly so susceptible of decomposition as uncoagulated albumen. Mr Hatchett kept it for a month under water, and yet it did not become putrid.

When this substance was digested for some hours in water, it gradually softened, and became white and opaque like newly coagulated albumen. When water is made to act upon it long, a small portion of it is taken up. The watery liquid is not precipitated by the infusion of tan; but nitromuriate of tin occasions a faint cloud.

According to Scheele, the mineral acids, when greatly diluted with water, dissolve a portion of coagulated albumen, which is thrown down again by the same acids concentrated.

When coagulated albumen is steeped in diluted nitric acid, the acid in about four weeks begins to acquire a yellow tinge, which becomes gradually deeper; but the albumen, though it becomes more opaque, is not dissolved. The yellow acid, when saturated with ammonia, becomes of a deep orange colour, but does not let fall any precipitate. When the albumen, thus treated, is immersed in ammonia, the liquid assumes a deep orange colour, inclining to blood red. The albumen is slowly dissolved, and the solution has a deep yellowish brown colour. If the albumen, after being steeped in nitric acid, be washed and then boiled in water, it is dissolved, and forms a pale yellow liquid, which gelatinizes when properly concentrased. If the gelatinous mass be again dissolved in boiling water, the solution is precipitated by tan and by nitro-muriate of tin. Hence we see that nitric acid has the property of converting coagulated albumen into gelatine.

Concentrated nitric acid dissolves coagulated albumen with effervescence, especially when assisted by heat. It becomes orange brown when mixed with ammonia, but no precipitate falls.

It is readily dissolved by a boiling lixivium of potash; ammonia is disengaged, and an animal soap is formed. This soap, when dissolved in water, and mixed with acetic or muriatic acids, lets fall a precipitate which is of a saponaceous nature. When heated gently some oil flows from it, and a brownish viscid substance remains. The alkalies, when diluted, and not assisted by heat, act upon it slowly and imperfectly.

These properties indicate sufficiently that coagulated albumen is a very different substance from uncoagulated albumen.

III. From the effects of nitric acid on albumen; and its products, when subjected to destructive distillation, it has been concluded that it consists of carbon, hydrogen, azote, and oxygen, in unknown proportions. As it yields more azotic gas to nitric acid, it has been considered as containing more of that principle than gelatine. It is obvious, however, that it does not differ much from that body, as nitric acid spontaneously converts it into gelatine. Mr Hatchett has rendered it very probable that it is the first of the soft part of animals that is formed, and that all the other soft parts are formed from it.

SECT. III. *Of Mucus.*

No word in chemistry has been used with less precision than *mucus*. Too many experimenters have made it serve as a common name for every animal substance which cannot be referred to any other class. Dr Bostock, in his excellent Papers on the Analysis of Animal Fluids, has endeavoured to fix the meaning of the word by ascertaining the properties of pure mucus. Fourcroy and Vauquelin have lately written an elaborate paper on the same subject.

From Bostock's experiments it appears, that if the solid matter obtained by evaporating saliva to dryness be re-dissolved in water and filtered, the solution will contain very little except mucus. He obtained mucus, also, by macerating an oyster in water and evaporating the liquid. Mucus, thus obtained, possesses the following properties:

1. It has much the appearance of gum arabic, excepting that, in general, it is rather more opaque; like it, it has little taste, dissolves readily in water, and forms an adhesive solution.

2. When evaporated to dryness it is transparent, inelastic, and has much the appearance of gum. It is insoluble in water, but dissolves readily in all the acids though very much diluted.

3. It does not dissolve in alcohol nor in ether.

4. It does not coagulate when heated; nor when concentrated by evaporation does its solution assume the form of a jelly.

5. It is not precipitated by the oxymuriate of mercury, nor by the infusion of galls.

6. The acetate of lead occasions a copious white precipitate when dropt into solutions containing mucus; the superacetate produces a much less striking effect.

7. Nitrate of silver likewise occasions a precipitate in solutions containing mucus.

8. When heated it assumes the appearance of horn, and when distilled it yields the common products of animal substances. According to Fourcroy and Vauquelin, horn, nails, hair, feathers, the epidermis, and the scales which form on the skin consist chiefly of mucus.

Many of the substances called *mucus* have the property of absorbing oxygen, and of becoming by that means insoluble in water. They resemble vegetable extractive matter in this respect.

SECT. IV. *Fibrin.*

If a quantity of blood, newly drawn, from an animal, be allowed to remain at rest for some time, a thick red clot gradually forms in it, and subsides. Separate this clot from the rest of the blood, put it into a linen cloth, and wash it repeatedly in water till it ceases to give out any colour or taste to the liquid; the substance which remains after this process is denominated *fibrin.* It has been long known to physicians under the name of the *fibrous part of the blood*, but has not till lately been accurately described.

It may be procured also from the muscles of animals. Mr Hatchett, to whom we are indebted for a very interesting set of experiments on this substance, cut a quantity of lean beef into small pieces, and macerated it in water for fifteen days, changing the water every day, and subjecting the beef to pressure at the same time, in order to squeeze out the water. As the weather was cold, it gave no signs of putrefaction during this process. The shreds of muscle, which amounted to about three pounds, were now boiled for five hours every day for three weeks in six quarts of fresh water, which was regularly changed every day. The fibrous part was now pressed, and dried by the heat of a water bath. After this treatment it might be considered as fibrin nearly as pure as it can be obtained.

Fibrin is of a white colour, has no taste nor smell, and is not soluble in water nor in alcohol. When newly extracted from blood, it is soft and elastic, and resembles very much the gluten of vegetables. Its colour deepens very much in drying. That which is extracted from muscle by boiling and maceration has a certain degree of transparency, and is not ductile but brittle. Its colour does not de nearly so much as the fibrin from blood.

It undergoes no change though kept exposed to the action of air; neither does it alter speedily though kept covered with water. Mr Hatchett kept a quantity of the fibrin which he had prepared from beef moistened with water during the whole month of April; it acquired a musty but not a putrid smell, neither were the fibres reduced to a pulpy mass. Even when kept two months under water, it neither became putrid, nor was converted into the fatty matter obtained by macerating recent muscle.

When fibrin is exposed to heat, it contracts very suddenly, and moves like a bit of horn, exhaling at the same time the smell of burning feathers. In a stronger heat it melts. When exposed to destructive distillation, it yields water, carbonate of ammonia, a thick heavy fetid oil, traces of acetic acid, carbonic acid, and carbureted hydrogen gas.

Acids dissolve fibrin with considerable facility. Sulphuric acid gives it a deep brown colour; charcoal is precipitated, and acetic acid formed. Muriatic acid dissolves it, and forms with it a green-coloured jelly. The acetic, citric, oxalic, and tartaric acids also dissolve it by the assistance of heat; and the solutions, when concentrated, assume the appearance of jelly. Alkalies precipitate the fibrin from acids in flakes, soluble in hot water, and resembling gelatine in its properties.

Diluted nitric acid occasions the separation of a good deal of azotic gas, as was first observed by Berthollet. Mr Hatchett steeped a quantity of fibrin in nitric acid diluted with thrice its weight of water for 15 days. The acid acquired a yellow tinge, and possessed all the properties of the nitric solution of albumen. The fibrin thus treated, dissolved in boiling water, and when concentrated by evaporation, became a gelatinous mass, soluble in hot water, and precipitated by tan and nitro-muriate of tin, and therefore possessing the properties of gelatine. Ammonia dissolves the greater part of the fibrin after it has been altered by nitric acid, The solution is of a deep orange colour, similar to the solution of albumen treated in the same way. Boiling nitric acid dissolves fibrin, except some fatty matter which swims on the surface. The solution resembles that of albumen; except that ammonia throws down a white precipitate, consisting chiefly of oxalate of lime. During the solution, prussic acid comes over, and carbonic acid gas mixed with nitrous gas; a considerable portion of oxalic acid is formed besides the fatty matter which swims.

The alkalies, while diluted, have but little effect upon fibrin; but when concentrated potash or soda is boiled upon it, a complete solution is obtained of a deep brown colour possessing the properties of soap. During the solution ammonia is disengaged. When the solution is saturated with muriatic acid, a precipitate is obtained similar to that from animal soap, except that it sooner becomes hard and soapy when exposed to the air.

The earths, as far as is known, have little or no action on fibrin. Neither has the action of the metallic oxides and salts been examined.

Fibrin is insoluble in alcohol, ether, and oils. The effect of other re-agents on it has not been examined.

From the properties above detailed, fibrin appears to be composed of the same constituents as gelatine and albumen; but it probably contains more carbon and azote and less oxygen. The close resemblance which it bears to albumen is very obvious from the experiments of Hatchett just detailed. Nitric acid converts both into *gelatine*, and alkalies convert both into a species of *oil*. Now, as all the soft parts of animals consist of combinations of these three genera, it follows, as Mr Hatchett has observed, that all the soft parts of animals may be either converted into gelatine or animal soap, both substances of the highest importance.

Fibrin exists only in the blood and the muscles of animals: but it is a genus which includes as many species as there are varieties in the muscles of animals; and the great diversity of these substances is well known. The muscles of fish, of fowl, and of quadrupeds, bear scarcely any resemblance to each other.

SECT. V. *Of Urea.*

Urea may be obtained by the following process: Evaporate by a gentle heat a quantity of human urine, voided six or eight hours after a meal, till it be reduced to the consistence of a thick syrup. In this state, when put by to cool, it concretes into a crystalline mass. Pour at different times upon this mass four times its weight of alcohol, and apply a gentle heat; a great part of the mass will be dissolved, and there will remain only a number of saline substances. Pour the alcohol solution into a retort, and distil by the heat of a sand-bath till the liquid, after boiling some time, is reduced to the consistence of a thick syrup. The whole of the alcohol is now separated, and what remains in the retort crystallizes as it cools. These crystals consist of the substance known by the name of *urea*.

Urea, obtained in this manner, has the form of crystalline plates crossing each other in different directions. Its colour is yellowish white: it has a fetid smell, somewhat resembling that of garlic or arsenic; its taste is strong and acrid, resembling that of ammoniacal salts; it is very viscid and difficult to cut, and has a good deal of resemblance to honey. When exposed to the open air, it very soon attracts moisture, and is converted into a thick brown liquid. It is extremely soluble in water; and during its solution a considerable degree of cold is produced. Alcohol dissolves it with facility, but scarcely in so large a proportion as water. The alcohol solution yields crystals much more readily on evaporation than the solution in water.

When nitric acid is dropt into a concentrated solution of urea in water, a great number of bright pearl-coloured crystals are deposited, composed of urea and nitric acid. No other acid produces this singular effect. The concentrated solution of urea in water is brown, but it becomes yellow when diluted with a large quantity of water. The infusion of nutgalls gives it a yellowish brown colour, but causes no precipitate; neither does the infusion of tan produce any precipitate.

When heat is applied to urea, it very soon melts, swells up, and evaporates with an insupportably fetid odour. When distilled, there comes over first benzoic acid, then carbonate of ammonia in crystals, some carbureted hydrogen gas, with traces of prussic acid and oil; and there remains behind a large residuum, composed of charcoal, muriate of ammonia, and muriate of soda. The distillation is accompanied with an almost insupportably fetid alliaceous odour.

When the solution of urea in water is kept in a boiling heat, and new water is added as it evaporates, the urea is gradually decomposed, a very great quantity of carbonate of ammonia is disengaged, and at the same time acetic acid is formed, and some charcoal precipitates.

When a solution of urea in water is left to itself for some time, it is gradually decomposed. A froth collects on its surface; air bubbles are emitted which have a strong disagreeable smell, in which ammonia and acetic acid are distinguishable. The liquid contains a quantity of acetic acid. The decomposition is much more rapid if a little gelatine be added to the solution. In that case more ammonia is disengaged, and the proportion of acetic acid is not so great.

When the solution of urea is mixed with one-fourth of its weight of diluted sulphuric acid, no effervescence takes place;

but, on the application of heat, a quantity of oil appears on the surface, which concretes upon cooling; the liquid which comes over into the receiver contains acetic acid, and a quantity of sulphate of ammonia remains in the retort dissolved in the undistilled mass. By repeated distillations, the whole of the urea is converted into acetic acid and ammonia.

When nitric acid is poured upon crystallized urea, a violent effervescence takes place, the mixture frothes, assumes the form of a dark red liquid, great quantities of nitrous gas, azotic gas, and carbonic acid gas, are disengaged. When the effervescence is over, there remains only a concrete white matter, with some drops of reddish liquid. When heat is applied to this residuum it detonates like nitrate of ammonia.

Muriatic acid dissolves urea, but does not alter it. Oxymuriatic acid gas is absorbed very rapidly by a diluted solution of urea; small whitish flakes appear, which soon become brown, and adhere to the sides of the vessel like a concrete oil. After a considerable quantity of oxymuriatic acid had been absorbed, the solution, left to itself, continued to effervesce exceeding slowly, and to emit carbonic acid and azotic gas. After this effervescence was over, the liquid contained muriate and carbonate of ammonia.

Urea is dissolved very rapidly by a solution of potash or soda, and at the same time a quantity of ammonia is disengaged; the same substance is disengaged when urea is treated with barytes, lime, or even magnesia. Hence it is evident, that this appearance must be ascribed to the muriate of ammonia, with which it is constantly mixed. When pure solid potash is triturated with urea, heat is produced, a great quantity of ammonia is disengaged; the mixture becomes brown, and a substance is deposited, having the appearance of an empyreumatic oil. One part of urea and two of potash, dissolved in four times its weight of water, when distil led, give out a great quantity of ammoniacal water; the residuum contains acetate and carbonate of potash.

When muriate of soda is dissolved in a solution of urea in water, it is obtained by evaporation, not in cubic crystals, its usual form, but in regular octahedrons. Muriate of ammonia, on the contrary, which crystallizes naturally in octahedrons, is converted into cubes, by dissolving and crystallizing it in the solution of urea.

SECT. VI. *Of Saccharine Matter.*

Sugar has never been found in animals in every respect similar to the sugar of vegetables; but there are certain animal substances which have so many properties in common with sugar, that they can scarcely be arranged under any other name. These substances are,

1. Sugar of milk.
2. Honey.
3. Sugar of diabetic urine.

1. Sugar of milk may be obtained by the following process: Let fresh whey be evaporated to the consistence of honey, and then allowed to cool; it concretes into a solid mass. Dissolve this mass in water, clarify it with the white of eggs, filter and evaporate to the consistence of a syrup; it deposites on cooling a number of brilliant white cubic crystals, which are *sugar of milk*.

When pure it has a white colour, a sweetish taste, and no smell. Its crystals are semitransparent regular parallelopipeds, terminated by four-sided pyramids. Its specific gravity, at the temperature of 55°, is 1·543. At that temperature it is soluble in seven times its weight of water; but is perfectly insoluble in alcohol. When burnt it emits the odour of caromel, and exhibits precisely the appearance of burning sugar. When distilled, it yields the same products as sugar, only the empyreumatic oil obtained has the odour of benzoic acid. When treated with nitric acid it yields *saclactic* acid. From these experiments, it appears that sugar of milk is specifically different from every kind of vegetable sugar at present known.

2. Honey is prepared by bees, and perhaps rather belongs to the vegetable than the animal kingdom. It has a white or yellowish colour, a soft and grained consistence, a saccharine and aromatic smell. By distillation it affords an acid phlegm and an oil, and its coal is light and spongy like that of the mucilages of plants. Nitric acid extracts from it oxalic acid, precisely as it does from sugar. It is very soluble in water, with which it forms a syrup, and like sugar passes to the vinous fermentation.

According to Proust, there are two kinds of honey; one always liquid, and the other solid and not deliquescent. They may be separated, he says, by means of alcohol.

3. The urine of persons labouring under the disease known to physicians by the name of *diabetes*, yields, when evaporated, a considerable quantity of matter which possesses properties analogous to sugar. This seems to have been first observed by Willis. When treated with nitric acid, it yielded the same proportion of oxalic acid as an equal quantity of common sugar would have done, making allowance for the saline substances present. No saclactic acid was formed. Hence it follows that this substance is not analogous to sugar of milk, but nearer common sugar in its properties. It has been supposed incapable of crystallizing regularly like common sugar. But I have seen it prepared by Dr Wollaston in small grains, having almost exactly the appearance of common white sugar.

SECT. VII. *Of Oils.*

The oily substances found in animals belong all to the class of fixed oils. They differ very much in their consistence, being found in every intermediate state from spermaceti, which is perfectly solid, to train oil, which is completely liquid. The most important of them are the following:

1. *Spermaceti.*—This peculiar oily substance is found in the cranium of the *physeter macrocephalus*, or spermaceti whale. It is obtained also from some other species. At first it is mixed with some liquid oil, which is separated by means of a woollen bag. The last portions are removed by an alkaline ley, and the spermaceti is afterwards purified by fusion. Thus obtained, it is a beautiful white substance, usually in small scales, very brittle, has scarcely any taste, and but little smell. It is distinguished from all other fatty bodies by the crystalline appearance which it always assumes. It melts, according to the experiments of Bostock, at the temperature of 112°. When sufficiently heated it may be distilled over without much alteration; but when distilled repeatedly it loses its solid form and becomes a liquid oil.

2. *Fat.*—This substance is found abundantly in different parts of animals. When pure it possesses the properties of the fixed oils. Its consistence varies from *tallow* or *suet*, which is brittle, to *hog's lard*, which is soft and semi-fluid. To obtain fat pure, it is cut in small pieces, well washed in water, and the membranous parts and vessels separated. It is then melted in a shallow vessel along with some water, and kept melted till the water is completely evaporated. Thus purified it is white, tasteless, and nearly insipid.

3. *Train oil.*—This liquid is extracted from the blubber of the whale, and from other fish. It forms a very important article of commerce, being employed for combustion in lamps, and for other purposes. It is at first thick; but on standing, a white mucilaginous matter is deposited, and the oil becomes transparent. It is then of a reddish brown colour, and has a disagreeable smell.

4. Though all the oily bodies found in animal substances belong to the class of fixed oils, yet there is a peculiar volatile oil which makes its appearance, and which is doubtless formed during the distillation of different animal bodies. Though this oil has now lost that celebrity which drew the attention of the older chemists to it, yet as its properties are peculiar, a short account of it will not be improper. It is usually called the *animal oil of Dippel,* because that chemist first drew the attention of chemists to it. It is usually obtained from the gelatinous and albuminous parts of animals. The horns are said to answer best. The product of the first distillation is to be mixed with water, and distilled with a moderate heat; the oil which is first obtained is the animal oil of Dippel.

It is colourless and transparent; its smell is strong and rather aromatic; it is almost as light and as volatile as ether; water dissolves a portion of it; and it changes syrup of violets green, owing, as is supposed, to its containing a little ammonia. The acids all dissolve it, and form with it a kind of imperfect soap. Nitrous acid sets it on fire. It forms with alkalies a soap. Alcohol, ether, and oils unite with it. When exposed to the air it becomes brown, and loses its transparency. It was formerly used as a specific in fevers.

SECT. VIII. *Of Animal Resins.*

Substances resembling resins are found in different animal bodies; and which, for that reason, may be called *animal resins*. Their properties are somewhat different from the vegetable resins, but they have not been all examined with precision. The following are the most remarkable of these substances.

1. *Resin of bile.*—This substance may be obtained by the following process: Into thirty-two parts of fresh ox bile pour one part of concentrated muriatic acid. After the mixture has stood for some hours, pass it through a filter, in order to separate a white coagulated substance. Pour the filtrated liquor, which has a fine green colour, into a glass vessel, and evaporate it by a moderate heat. When it has arrived at a certain degree of concentration, a green-coloured substance precipitates. Decant off the clear liquid, and wash the precipitate in a small quantity of pure water. This precipitate is the *basis of bile*, or the *resin of bile*, as it is sometimes called.

The resin of bile is of a dark brown colour; but when spread out upon paper or on wood, it is a fine grass green: its taste is intensely bitter.

When heated to about 122° it melts; and if the heat be still farther increased it takes fire and burns with rapidity. It is insoluble in water, but soluble in alcohol; and water precipitates it from that liquid.

It is soluble also in alkalies, and forms with them a compound which has been compared to a soap. Acids, when sufficiently diluted, precipitate it both from water and alkalies without any change; but if they be concentrated, the precipitate is re-dissolved.

2. *Ambergris.* This substance is found floating on the sea, near the coasts of India, Africa, and Brazil, usually in small pieces, but sometimes in masses of fifty or one hundred pounds weight. Various opinions have been entertained concerning its origin. Some affirmed that it was the concrete juice of a tree; others thought it a bitumen; but it is now considered as pretty well established, that it is a concretion formed in the stomach or intestines of the *physeter macrocephalus*, or spermaceti whale.

Ambergris when pure is a light soft substance which swims on water. Its specific gravity varies from 0·78 to 0.92, according to Brisson; Bouillon La Grange, who has lately published an analysis of it, found its specific gravity from 0·849 to 0·844. Its colour is ash grey, with brownish yellow and white streaks. It has an agreeable smell, which improves by keeping. Its taste is insipid.

According to Bouillon La Grange it is composed of—

52·7	adipocire
30·8	resin
11·1	benzoic acid
5·4	charcoal
100·0	

3. *Castor.* This substance is obtained from the beaver. In each of the inguinal regions of that animal there are two bags, a large and a small. The large one contains the true castor; the small one a substance which has some resemblance to it, but which is in much less estimation. We are indebted to Bouillon La Grange for a set of experiments on it.

Castor is of a yellow colour; and when newly taken from the animal it is nearly fluid. But by exposure to the atmosphere it gradually hardens, becomes darker coloured, and assumes a resinous appearance. Its taste is bitter and acrid, and its odour strong and aromatic.

From the analysis of Bouillon La Grange, we learn that castor contains the following ingredients:

1. Carbonate of potash
2. Carbonate of lime
3. Carbonate of ammonia
4. Iron
5. Resin
6. A mucilaginous extractive matter
7. A volatile oil

The properties of the resin are analogous to those of the resin of bile.

Sect. IX. *Of Acids.*

The acids which have been discovered ready formed, and constituting a part of animal bodies, are the following:

1. Phosphoric
2. Sulphuric
3. Muriatic
4. Carbonic
5. Benzoic
6. Uric
7. Rosacic
8. Amniotic
9. Oxalic
10. Formic
11. Acetic
12. Malic.

1. The phosphoric acid is by far the most abundant of all the acids found in animals. Combined with lime, it constitutes the basis of bone; and the phosphate of lime is found in the muscles, and almost all the solid parts of animals; neither are there many of the fluids from which it is absent. In the blood, phosphoric acid is found combined with oxide of iron; and in the urine it exists in excess, holding phosphate of lime in solution.

2. Sulphuric acid can scarcely be considered as a component part of any of the substances belonging to the human

body. It is said, indeed, to occur sometimes in urine combined with soda. It is, however, a very common constituent of the liquid contents of the inferior animals. Thus sulphate of soda is found in the liquor of the amnios of cows, and sulphate of lime occurs usually in the urine of quadrupeds.

3. Muriatic acid occurs in most of the fluid animal substances, and is almost always combined with soda, constituting common salt.

4. Carbonic acid has been detected in fresh human urine by Proust, and it occurs in the urine of horses and cows abundantly, partly combined with lime.

5. Benzoic acid was first discovered in human urine by Scheele; and Fourcroy and Vauquelin have found it abundantly in the urine of cows. Proust has detected it in the blood, the albumen of an egg, in glue, silk, and wool, in the sponge, different species of algæ, and even in mushrooms.

6. Uric or lithic acid was discovered by Scheele in 1776. It is the most common constituent of urinary calculi, and exists also in human urine. That species of calculus which resembles wood in its colour and appearance is composed entirely of this substance. It was called at first lithic acid; but this name, in consequence of the remarks made by Dr Pearson on its impropriety, has been laid aside, and that of *uric* acid substituted in its place.

7. Rosacic. During intermittent fevers urine deposites a very copious precipitate, which has been long known to physicians under the name of *lateritious sediment*. This sediment always makes its appearance at the crisis of fevers. In gouty people, the same sediment appears in equal abundance towards the end of a paroxysm of the disease; and if this sediment suddenly disappears after it has begun to be deposited, a fresh attack may be expected. Scheele consi-

dered this sediment as uric acid mixed with some phosphate of lime; and the same opinion has been entertained by other chemists: but Proust affirms that it consists chiefly of a different substance, to which he has given the name of *rosacic* acid from its colour, mixed with a certain proportion of uric acid and phosphate of lime. This rosacic acid, he informs us, is distinguished from the uric by the facility with which it dissolves in hot water, the violet precipitate which it occasions in muriate of gold, and by the little tendency which it has to crystallize.

8. Amniotic acid has been lately discovered by Vauquelin and Buniva in the liquor of the amnios of the cow, and may be obtained in white crystals by evaporating that liquid slowly. Hence they have given it the name of *amniotic acid*. It is of a white and brilliant colour; its taste has a very slight degree of sourness; it reddens the tincture of turnsole; it is scarcely soluble in cold water, but very readily in hot water, from which it separates in long needles as the solution cools. It is soluble also in alcohol, especially when assisted by heat.

9. Oxalic acid has hitherto been found only in a few urinary calculi by Vauquelin and Fourcroy.

10. Formic acid has been hitherto found only in the *formica rufa*, or red ant.

11. Acetic. This acid has been detected in urine by Proust. It exists also in the *formica rufa*, or red ant, as has been demonstrated by the experiments of Fourcroy and Vauquelin. It appears also, from the labours of these philosophers and of Thenard, that the acid found in milk is the acetic, disguised a little by holding some salts in solution.

12. Malic acid. This acid has been lately detected by Fourcroy and Vauquelin in the acid liquid obtained from the *formica rufa*. When this liquid is saturated with lime, if

acetate of lead be dropt into the solution, a copious precipitate falls, which is soluble in acetic acid. Fourcroy and Vauquelin exposed the precipitate to the proper trials, and ascertained that it was malate of lead.

SECT. X. *Of Alkalies, Earths, and Metals.*

I. All the alkalies have been found in the fluids of animals.

1. Potash is rather uncommon in the human fluids; but it has been detected in the milk of cows, and it has been found abundantly in the urine of quadrupeds.

2. Soda exists in all the fluids, and, seems always to be combined with albumen. Phosphate and muriate of soda are also found. It is this alkali which gives animal fluids the property of tinging vegetable blues green.

3. Ammonia has been detected by Proust in urine; and it is formed in abundance during the putrefaction of most animal bodies.

II. The only earths hitherto found in animals are lime, magnesia, and silica.

1. Lime exists in great abundance in all the larger animals. Combined with phosphoric acid, it constitutes the basis of bones, while shells are composed of carbonate of lime. Phosphate of lime is found also in the muscles and other solid parts, and it is held in solution by almost all the fluids.

2. Magnesia has been detected in human urine by Fourcroy and Vauquelin, combined with phosphoric acid and ammonia. It constitutes also sometimes a component part of the urinary calculi.

3. Silica has not hitherto been detected in any of the component parts of animals, except hair; but Fourcroy and Vauquelin found it in urinary calculi,

III. The metals found in animals are two; namely, iron and manganese.

1. Iron combined with phosphoric acid is a constituent part of the blood. Its presence was first ascertained by Manghini, who proved at the same time that it does not exist in the solid parts of animals. It is said to exist also in bile.

2. Manganese has been found in human hair, but scarcely in any other animal substance.

CHAP. II.

PARTS OF ANIMALS.

The different substances which compose the bodies of animals may be arranged under the following heads:

1. Bones and shells
2. Horns and nails
3. Muscles
4. Skin
5. Membranes
6. Tendons and ligaments
7. Glands
8. Brain and nerves
9. Marrow
10. Hair and feathers
11. Silk and similar bodies.

Besides these substances, which constitute the solid parts of the bodies of animals, there are a number of fluids, the most important of which is the *blood*, which pervades every part of the system in all the larger animals: The rest are known by the name of *secretions*, because they are formed, or *secreted* as the anatomists term it, from the blood. The principal animal secretions are the following:

1. Milk
2. Eggs
3. Saliva
4. Pancreatic juice

5. Bile
6. Cerumen
7. Tears
8. Liquor of the pericardium
9. Humours of the eye
10. Mucus of the nose, &c.
11. Sinovia
12. Semen
13. Liquor of the amnios
14. Poisonous secretions
15. Air

Various substances are separated either from the blood or the food on purpose to be afterwards thrown out of the body as useless or hurtful. These are called *excretions*. The most important of them are,

1. Sweat
2. Urine
3. Fæces.

Besides the liquids which are secreted for the different purposes of healthy animals, there are others which make their appearance only during disease, and which may therefore be called *morbid secretions*. The most important of these are the following:

1. Pus
2. The liquor of dropsy
3. The liquor of blisters.

To these we must add several solid bodies, which are occasionally formed in different cavities in consequence of the diseased action of the parts. They may be called *morbid concretions*. The most remarkable of them are the following:

1. Salivary calculi
2. Concretions in the lungs, liver, brain, &c.
3. Intestinal calculi
4. Biliary calculi
5. Urinary calculi
6. Gouty calculi.

These different substances shall form the subjects of the following sections:

SECT. I. *Of Bones, Shells, and Crusts.*

By *bones* are meant those hard, solid, well-known substances, to which the firmness, shape, and strength of animal bodies are owing; which, in the larger animals, form as it were, the ground-work upon which all the rest is built. In man, in quadrupeds, and many other animals, the bones are situated below the other parts, and scarcely any of them are exposed to view; but shell-fish and snails have a hard covering on the outside of their bodies, evidently intended for defence. As these coverings, though known by the name of *shells*, are undoubtedly of a bony matter, I shall include them in this section.

1. *Bones.*

The bones are the most solid parts of animals. Their texture is sometimes dense, at other times cellular and porous, according to the situation of the bone. They are white, of a lamellar structure, and not flexible nor softened by heat. Their specific gravity differs in different parts. That of adults teeth is 2·2727; the specific gravity of childrens teeth is 2·0833.

The component parts of bones are chiefly four; namely, the earthy salts, fat, gelatine, and cartilage.

1. The earthy salts may be obtained either by calcining the bone to whiteness, or by steeping it for a sufficient length of time in acids. In the first case, the salts remain in the state of a brittle white substance; in the second they are dissolved, and may be thrown down by the proper precipitants. These earthy salts are four in number: 1. Phosphate of lime,

which constitutes by far the greatest part of the whole. 2. Carbonate of lime. 3. Phosphate of magnesia, lately discovered by Fourcroy and Vauquelin. It occurs in the bones of all the inferior animals examined by these indefatigable chemists, but could not be detected in human bones. 4. Sulphate of lime, detected by Mr Hatchett in a very minute proportion.

2. The proportion of fat contained in bones is various. By breaking bones in small pieces, and boiling them for some time in water, Mr Proust obtained their fat swimming on the surface of the liquid. It weighed, he says, one-fourth of the weight of the bones employed. This proportion appears excessive, and can scarcely be accounted for without supposing that the fat still retained water.

3. The gelatine is separated by the same means as the fat, by breaking the bones in pieces and boiling them long enough in water. The water dissolves the gelatine, and gelatinizes when sufficiently concentrated. Hence the importance of bones in making portable soups, the basis of which is concrete gelatine, and likewise in making glue. By this process Proust obtained from powdered bones about one-sixteenth of their weight of gelatine.

4. When bones are deprived of their gelatine by boiling them in water, and of their earthy salts by steeping them in diluted acids, there remains a soft white elastic substance, possessing the figure of the bones, and known by the name of *cartilage*. From the experiments of Hatchett, it appears that this substance has the properties of coagulated albumen. Like that substance, it becomes brittle and semitransparent when dried, is readily soluble in hot nitric acid, is converted into gelatine by the action of diluted nitric acid; for it is soluble in hot water, and gelatinises on cooling, and ammonia dissolves it and assumes a deep orange colour.

Ox bones, according to the analysis of Fourcroy and Vauquelin, are composed of

51·0	solid gelatine
37·7	phosphate of lime
10·0	carbonate of lime
1·3	phosphate of magnesia.
100·0	

From the calcined bones of horses and sheep, fowls, and fishes, they extracted about one-thirtysixth part of phosphate of magnesia.

The only bone hitherto observed altogether destitute of cartilage is the enamel of the teeth. When the raspings of bones are steeped in diluted acids, the cartilage alone remains undissolved. Now, when the raspings of enamel are treated in this manner, Mr Hatchett observed that the whole was dissolved without any residuum whatever. If we believe Fourcroy and Vauquelin, the enamel of teeth is composed of

72·9	phosphate of lime
27·1	gelatine and water
100·0	

But the most complete analysis of teeth has been made by Mr Pepys, and his results agree exactly with those of Hatchett. He found the enamel of the teeth composed of

78	phosphate of lime.
6	carbonate of lime
16	loss and water
100	

2. *Shells.*

Under the name of *shells* I include all the bony coverings of the different species of shell fish. Egg shells, also, from the similarity of their texture, belong to the same head. For almost all the knowledge of these substances that we possess, we are indebted to the late important dissertations of Mr Hatchett. A few detached facts, indeed, had been observed by other chemists; but his experiments gave us a systematic view of the constituents of the whole class.

Shells, like bones, consist of calcareous salts united to a soft animal matter; but in them the lime is united chiefly to carbonic acid, whereas in bones it is united to phosphoric acid. In shells the predominating ingredient is carbonate of lime; whereas in bones it is phosphate of lime. This constitutes the characteristic difference in their composition.

Mr Hatchett has divided shells into two classes. The first are usually of a compact texture, resemble porcelain, and have an enamelled surface, often finely variegated. The shells belonging to this class have been distinguished by the name of *porcelaneous shells*. To this class belong the various species of *voluta, cypræa*, &c. The shells belonging to the second class are usually covered with a strong epidermis, below which lies the shell in layers, and composed entirely of the substance well known by the name of *mother-of-pearl*. They have been distinguished by the name of *mother-of-pearl shells*. The *shell* of the *fresh water muscle*, the *haliotis iris*, the *turbo olearius*, are examples of such shells. The shells of the first of these classes contain a very small portion of soft animal matter; those of the second contain a very large portion. Hence we see that they are extremely different in their composition.

1. Porcelaneous shells, when exposed to a red heat, crackle and lose the colour of their enamelled surface. They emit no smoke or smell; their figure continues unaltered, their colour becomes opaque white, tinged partially with pale grey. They dissolve when fresh with effervescence in acids, and without leaving any residue; but if they have been burnt,

there remains always a little charcoal. The solution is transparent, gives no precipitate with ammonia or acetate of lead; of course it contains no sensible portion of phosphate or sulphate of lime. Carbonate of ammonia throws down an abundant precipitate of carbonate of lime. Porcelaneous shells, then, consist of carbonate of lime cemented together by a small portion of an animal matter, which is soluble in acids, and therefore resembles gelatine.

2. Mother-of-pearl shells when exposed to a red heat crackle, blacken, and emit a strong fetid odour. They exfoliate, and become partly dark grey, partly a fine white. When immersed in acids they effervesce at first strongly; but gradually more and more feebly, till at last the emission of air-bubbles is scarcely perceptible. The acids take up only lime, and leave a number of thin membranous substances, which still retain the form of the shell. From Mr Hatchett's experiments we learn that these membranes have the properties of coagulated albumen. Mother of pearl shells, then, are composed of alternate layers of coagulated albumen and carbonate of lime, beginning with the epidermis, and ending with the last formed membrane.

Pearl, a well known globular concretion which is formed in some of these shells, resembles them exactly in its structure and composition. It is a beautiful substance of a bluish white colour, iridescent, and brilliant. It is composed of concentric and alternate coats of thin membrane and carbonate of lime. Their iridescence is obviously the consequence of the lamellated structure.

3. *Crusts.*

By crusts we understand those bony coverings of w
the whole external surface of crabs, lobsters, and c
milar sea animals are composed. Mr Hatchett fo
composed of three ingredients: 1. A cartilaginous

possessing the properties of coagulated albumen; 2. Carbonate of lime; 3. Phosphate of lime. By the presence of this last substance they are essentially distinguished from shells, and by the great excess of carbonate of lime above the phosphate they are equally distinguished from bones. Thus the crusts lie intermediate between bones and shells, partaking of the properties and constitution of each. The shells of the eggs of fowls must be referred likewise to the class of crusts, since they contain both phosphate and carbonate of lime. The animal cement in them, however, is much smaller in quantity. From the experiments of Berniard and Hatchett, it is extremely probable that the shells of snails are composed likewise of the same ingredients, phosphate of lime having been detected in them by these chemists.

SECT. II. *Of Horns, Nails, and Scales.*

In the last Section I treated of those hard parts of animals which were inflexible and incapable of being softened by heat, and which contained a great portion of calcareous salts; but there is another set of hard parts which possess considerable elasticity, which are softened by heat, and which contain but a very small portion of calcareous matter. This set comprehends the substances well known under the names of *horn*, *nails*, and *scales*.

1. *Horns* are well known substances that are attached to the foreheads of oxen, sheep, and various other animals. They are not very hard, as they may be easily cut with a knife or rasped with a file; but they are so tough, as not to be capable of being pounded in a mortar. When in thin plates they have a degree of transparency, and have been sometimes substituted for glass in windows. When heated

sufficiently they become very soft and flexible, so that their shape may be altered considerably. Hence they may be gradually squeezed into a mould, and wrought into various forms, as is well known. When strongly heated in a Papin's digester, they are said to be converted into a gelatinous mass, which possesses the properties of gelatine.

The quantity of earthy matter which they contain is exceedingly small. Mr Hatchett burnt 500 grains of ox horn. The residuum was only 1.5 grain, and not the half of this was phosphate of lime. Seventy-eight grains of the horn of the chamois left only 0·5 of residue, of which less than the half was phosphate of lime. They consist chiefly of a membranous substance, which possesses the properties of coagulated albumen; and probably they contain also a little gelatine.

2. The *nails*, which cover the extremities of the fingers, are attached to the epidermis, and come off along with it. Mr Hatchett has ascertained that they are composed chiefly of a membranous substance, which possesses the properties of coagulated albumen. They seem to contain also a little phosphate of lime. Water softens but does not dissolve them; but they are readily dissolved and decomposed by concentrated acids and alkalies. Hence it appears that nails, agree with horn in their nature and composition. Under the head of nails must be comprehended the talons and claws of the inferior animals, and likewise their hoofs, which differ in no respect from horn.

3. *Scales* of animals are of two kinds; some, as those of serpents and other amphibious animals, have a striking resemblance to horn; while those of fish bear a greater resemblance to mother-of-pearl. The composition of these two kinds of shells is very different.

The scales of fish, are composed of different membranous laminae. When immersed for four or five hours in nitric acid, they become transparent, and perfectly membranaceous. The acid, when saturated with ammonia, gives a copious precipitate of phosphate of lime. Hence they are composed of alternate layers of membrane and phosphate of lime. To this structure they owe their brilliancy. Mr Hatchett found the spicula of the shark's skin to be similar in its composition, but the skin itself yielded no phosphate of lime.

The horny scales of serpents, on the other hand, are composed alone of a horny membrane, and are destitute of phosphate of lime. They yielded, when boiled, but slight traces of gelatine; the horn-like crusts which cover certain insects and other animals appear, from Mr Hatchett's experiments, to be nearly similar in their composition and nature.

SECT. III. *Of the Muscles of Animals.*

After the hard parts of animals have been examined, it remains for us to consider the composition of the *soft* parts. Of these, the muscles naturally claim our attention in the first place, as being the most important.

The muscular parts of animals are known in common language by the name of *flesh*. They constitute a considerable portion of the food of man.

Muscular flesh is composed of a great number of fibres or threads, commonly of a reddish or whitish colour; but its appearance is too well known to require any description. Hitherto it has not been subjected to any accurate chemical analysis.

When a muscle is cut in small pieces, and well washed with water, the blood and other liquids contained in it are separated, and part of the muscular substance also is dissolved. The muscle, by this process, is converted into a white fibrous substance, still retaining the form of the original body. The water assumes the colour which results from mixing water with some blood. When heated it coagulates; brown flakes swim on the surface, consisting of albumen combined with the colouring matter of the blood: some fibrin likewise precipitates. If the evaporation be continued, more albumen precipitates, and at last the whole assumes the form of a jelly. When evaporated to dryness, and treated with alcohol, the gelatine thus formed, together with a little phosphate of soda and of ammonia, remains undissolved; but the alcohol dissolves a peculiar *extractive* matter, first observed by Thouvenel. This matter may be obtained by evaporating the alcohol to dryness. It has a reddish brown colour, a strong acrid taste, and aromatic odour.

If the muscle, after being thus treated with cold water, be boiled for a sufficient time in water, an additional portion of the same substances is separated from it. Some albumen collects on the surface in the form of scum, accompanied with some melted fat. The water, when sufficiently concentrated by evaporation, assumes the form of a jelly. When evaporated to dryness, and treated with alcohol, the gelatine and phosphoric salts remain, while the extractive matter of Thouvenel is dissolved, and may be obtained by evaporating to dryness.

The muscle, thus treated with water, is left in the state of grey fibres, insoluble in water, and becoming brittle when dry. This substance possesses all the properties of *fibrin*.

From these facts, ascertained by Thouvenel and Fourcroy, it appears that the muscles are composed chiefly of fibrin, to which they owe their fibrous structure and their form, and that they contain also

2. Albumen
3. Gelatine
4. Extractive
5. Phosphate of soda
6. Phosphate of ammonia
7. Phosph. of lime and carb. of do.

For the discovery of the last ingredients we are indebted to Mr Hatchett, who found that 500 parts of beef muscle left, after combustion, a residuum of 25·6 parts, consisting chiefly of these salts.

The muscles of different animals differ exceedingly from each other in their appearance and properties, at least as articles of food; but we know little of their chemical differences. The observations of Thouvenel alone were directed to that object, and they are imperfect. The flesh of the *ox* contains, according to him, the greatest quantity of insoluble matter, and leaves the greatest residuum when dried; the flesh of the *calf* is more aqueous and mucous: the land and water *turtle* yields more matter to water than the muscle of the ox; but Thouvenel ascribes the difference to foreign bodies, as ligaments, &c. mixed with the muscle of the turtle: *snails* yield to water a quantity of matter intermediate between that given by beaf and veal: with them the muscles of *frogs, cray fish,* and *vipers,* agree nearly in this respect; but the muscles of fresh water fish, notwithstanding their softness, yield a considerably smaller proportion.

SECT. IV. *Of the Skin.*

The skin is that strong thick covering which envelopes the whole external surface of animals. It is composed chiefly of two parts: a thin white elastic layer on the outside, which is called *epidermis* or *cuticle;* and a much thicker layer, composed of a great many fibres closely interwoven, and disposed in different directions; this is called the *cutis,* or *true skin.* The *epidermis* is that part of the skin which is raised in blisters.

1. The epidermis is easily separated from the cutis by maceration in hot water. It possesses a very great degree of elasticity.

It is totally insoluble in water and in alcohol. Pure fixed alkalies dissolve it completely, as does lime likewise, though slowly. Sulphuric and muriatic acids do not dissolve it, at least they have no sensible action on it for a considerable time; but nitric acid soon deprives it of its elasticity, and causes it to fall to pieces.

If the cuticle be tinged with nitric acid, the application of ammonia to it is well known to give it instantaneously a deep orange colour. Now, as Hatchett has shown that this change is also produced upon coagulated albumen in the same circumstances, and as the epidermis resembles that substance in all the properties above detailed, it can scarcely be doubted that it is any thing else than a peculiar modification of coagulated albumen.

2. The cutis is a thick dense membrane, composed of fibres interwoven like the texture of a hat. When it is macerated for some hours in water, and agitation and pressure are employed to accelerate the effect, the blood, and all the extraneous matter with which it was loaded, are separated from it, but its texture remains unaltered. On evaporating the water employed, a small quantity of gelatine may be obtained. No subsequent maceration in cold water has any farther effect. When distilled it yields the same products as fibrin. The concentrated alkalies dissolve it, converting it into oil and ammonia. Weak acids soften it, render it transparent, and at last dissolve it. Nitric acid converts it into oxalic acid and fat, while, at the same time, azotic gas and prussic acid are emitted. When heated it contracts, and then swells, exhales a fetid odour, and leaves a dense charcoal, difficult to incinerate. By spontaneous decomposition in water or moist earth, it is converted into a fatty matter and into ammonia, which compose a kind of soap. When allowed to remain long in water, it softens and putrefies, being converted into a kind of jelly. When long boiled in wa-

ter it becomes gelatinous, and dissolves completely, constituting a viscid liquor, which, by proper evaporation, is converted into glue. Hence the cutis of animals is commonly employed in the manufacture of glue.

From these facts the cutis appears to be a peculiar modification of gelatine, enabled to resist the action of water, partly by the compactness of its texture, and partly by the viscidity of the gelatine of which it is formed; for those skins which dissolve most readily in boiling water afford the worst glue. Mr Hatchett has observed that the viscidity of the gelatine obtained from skins is nearly inversely as their flexibility, the supplest hides always yielding the weakest glue; but this glue is very soon obtained from them by hot water. The skin of the eel is very flexible, and affords very readily a great proportion of gelatine. The skin of the shark also readily yields abundance of gelatine; and the same remark applies to the skins of the hare, rabbit, calf and ox; the difficulty of obtaining the glue and its goodness always increasing with the toughness of the hide. The hide of the rhinoceros, which is exceedingly strong and tough, far surpasses the rest in the difficulty of solution and in the goodness of its glue. When skins are boiled, they gradually swell and assume the appearance of horn: then they dissolve slowly.

3. As to the *rete mucosum*, or the mucous substance, situated between the cutis vera and epidermis, its composition cannot be determined with precision, because its quantity is too small to admit of examination. It is known that the black colour of negroes depends upon a black pigment, situated in this substance. Oxymuriatic acid deprives it of its black colour, and renders it yellow. A negro, by keeping his foot for some time in water impregnated with that acid, deprived it of its colour, and rendered it nearly white; but in a few days the black colour returned again with its former

intensity. This experiment was first made by Dr Beddoes on the fingers of a negro.

SECT. V. *Of Membranes, Tendons, Ligaments, and Glands.*

These substances have not hitherto been subjected to a rigid chemical analysis. But from the properties which have been observed, they appear to have a closer resemblance to the skin than to any other animal substance.

1. The membranes are thin semitransparent bodies which envelope certain parts of the body, especially the viscera; such as, the dura and pia mater, the plura, the peritoneum, the periosteum, &c. These substances are soft and pliable; when macerated in water, they swell, and become somewhat pulpy; and by continued decoction in hot water they are almost completely dissolved, and the solution concretes into gelatine. They are convertible of course into the same substance as the cutis by decoction; hence we must consider their composition as similar. Like hides they may also be tanned and converted into leather. From the experiments of Mr Hatchett, it appears that they contain no phosphate of lime as a constituent part, and scarcely any saline ingredients; for when calcined they leave but a very inconsiderable residuum. Thus 250 grains of hog's bladder left only 0·02 grain of residuum.

2. The tendons are strong, pearl-coloured, brilliant bodies, which terminate the muscles, and attach them to the bones, and are known in common language by the name of *sinews*. When boiled they assume the form of a semitransparent gelatinous substance, of a pleasant taste, well known in boiled meat. If the decoction be continued they dissolve completely, and are converted into gelatine. From these facts we

are authorized to conclude, that the composition of the tendons is similar to that of the membranes and cutis.

3. The ligaments are strong bands which bind the bones together at the different joints: they are fibrous substances, very dense and strong, and somewhat elastic. When boiled they yield a portion of gelatine, but they resist the action of water with great obstinacy, and after a great deal of boiling retain their form, and even their strength. The ligaments, then, differ essentially from the two last species. How far they resemble coagulated albumen remains to be ascertained. It is not unlikely that they will form a genus apart.

4. The glands are a set of bodies employed to form or to alter the different liquids which are employed for different purposes in the animal body. There are two sets of them: the *conglobate*, which are small, scattered in the course of the lymphatics; and the *conglomerate*, such as the liver, kidneys, &c. Fourcroy supposes the first of these to be composed of gelatine; but this is not very probable. The structure of the large glands has been examined by anatomists with great care; but we are still ignorant of their composition. Indeed the present state of chemistry scarcely admits of an accurate analysis of these complicated bodies.

SECT. VI. *Of the Brain and Nerves.*

The brain and nerves are the instruments of sensation, and even of motion; for an animal loses the power of moving a part the instant that the nerves which enter it are cut.

The brain and nerves have a strong resemblance to each other; and it is probable that they agree also in their composition. But hitherto no attempt has been made to analyse the nerves. The only chemists who have examined the nature of brain are Mr Thouret and Mr Fourcroy.

The brain consists of two substances, which differ from each other somewhat in colour, but which, in other respects, seem to be of the same nature. The outermost matter,* having some small resemblance in colour to wood-ashes, has been called the *cineritious* part; the innermost has been called the *medullary* part.

Brain has a soft feel, not unlike that of soap; its texture appears to be very close; its specific gravity is greater than that of water.

When brain is triturated in a mortar with diluted sulphuric acid, part is dissolved; the rest may be separated, by filtration, in the form of a coagulum. The acid liquor is colourless. By evaporation, the liquid becomes black, sulphurous acid is exhaled, and crystals appear; and when evaporated to dryness, a black mass remains behind. When this mass is diluted with water, a quantity of charcoal separates, and the water remains clear: The brain is completely decomposed, a quantity of ammonia combines with the acid and forms sulphate of ammonia, while charcoal is precipitated. The water, by evaporation and treatment with alcohol, yields sulphates of ammonia and lime, phosphoric acid, and phosphates of soda and ammonia. Brain therefore contains

Phosphate of lime
——— soda
——— ammonia.

Traces also of sulphate of lime can be discovered in it. The quantity of these salts is very small; altogether they do not amount to $\frac{1}{130}$th part.

Diluted nitric acid, when triturated with brain, likewise dissolves a part, and coagulates the rest. The solution is transparent. When evaporated till the acid becomes concentrated, carbonic acid gas and nitrous gas are disengaged; an effervescence takes place, white fumes appear, an immense quantity of ammonia is disengaged, a bulky charcoal remains mixed with a considerable quantity of oxalic acid.

When brain is gradually evaporated to dryness by the heat of a water bath, a portion of transparent liquid separates at first from the rest, and the residuum, when nearly dry, acquires a brown colour; its weight amounts to about one-fourth of the fresh brain. It may still be formed into an emulsion with water, but very soon separates again spontaneously.

When alcohol is repeatedly boiled upon this dried residuum till it ceases to have any more action, it dissolves about five-eighths of the whole. When this alcohol cools, it deposites a yellowish white substance, composed of brilliant plates. When kneaded together by the fingers, it assumes the appearance of a ductile paste: at the temperature of boiling water it becomes soft, and when the heat is increased it blackens, exhales empyreumatic and ammoniacal fumes, and leaves behind it a charry matter. When the alcohol is evaporated, it deposites a yellowish black matter, which reddens paper tinged with turnsole, and readily diffuses itself through water.

Pure concentrated potash dissolves brain, disengaging a great quantity of ammonia.

SECT. VII. *Marrow.*

The hollows of the long bones are in living animals filled with a peculiar species of fat matter, to which the name of *marrow* has been given. In some bones this matter is a good deal mixed with blood, and has a red colour; in others, as the thigh bones, it is purer, and has a yellow colour. Various experiments on this matter were made by the older chemists, showing it to be analogous to animal fats, and pointing out some of its peculiarities. Berzelius has lately examined it in detail, and published the results of his experiments. The marrow on which his trials were made was obtained from the thigh bone of an ox.

Marrow, freed from its impurities, has a white colour with a shade of blue; its taste is insipid and rather sweetish. It softens by the heat of the hand, and melts when heated to 113°. When cooled slowly it crystallizes in sphericles like olive oil. It burns with a flame like tallow. When distilled it gives first a transparent fluid yellowish oil, accompanied by carbonic acid gas, water, and heavy inflammable air. Afterwards there comes over a white solid oil, accompanied by a less copious evolution of gaseous bodies, and which does not become dark coloured, as happens when tallow is distilled. This had already been observed by Neumann. This solid oil has a disagreeable smell, amounts to 0·8 of the marrow distilled, reddens vegetable blues, and when boiled in water gives out a portion of sebacic acid, which Berzelius considers as benzoic acid.

The empyreumatic oil combines readily with alkalies and their carbonates. With the latter it forms a snow white soap, insoluble in water, though it increases in bulk when placed in contact with that liquid. It combines also with the earths, and forms soaps likewise insoluble in water.

The water which comes over during the distillation of marrow is colourless, has a fetid and sour smell, and an empyreumatic taste. It contains a little acetic acid, empyreumatic oil, and probably benzoic acid; but exhibits no traces of ammonia.

The gaseous products amount to one-tenth of the marrow distilled. They contain no sulphur nor phosphorus, and consist of carbonic acid and heavy inflammable air, which burns with a white flame, and seems to contain oil in solution.

The charry matter in the retort amounts to 0·05 of the marrow distilled. It is dark brown, heavy and brilliant. It is incinerated with difficulty; and leaves an ash consisting of phosphate of lime, carbonate of lime, and some soda.

Marrow combines with alkalies and forms soap. Boiling alcohol and ether dissolve a small portion of it, which precipitates again as the solution cools.

Marrow, from the thigh bone of an ox, was found by Berzelius to be composed of the following substances:

Pure marrow	0·96
Skins and blood-vessels	0·01
Albumen Gelatine Extractive Peculiar matter Water	0·03
	1·00

From the preceding detail it appears, that pure marrow is a species of fixed oil, possessing peculiar properties, and approaching somewhat to butter in its nature.

SECT. VIII. *Of Hair and Feathers.*

These substances cover different parts of animals, and are obviously intended by Nature to protect them from the cold. For this, their softness and pliability, and the slowness with which they conduct heat, render them peculiarly proper.

1. *Hair* is usually distinguished into various kinds, according to its size and appearance. The strongest and stiffest of all is called *bristle*: of this kind is the hair on the backs of hogs. When remarkably fine, soft, and pliable, it is called *wool*; and the finest of all is known by the name of *down*.

But all these varieties resemble one another very closely in their composition.

Vanquelin has lately published a curious set of experiments on the analysis of human hair of various colours. Though hair is insoluble in boiling water, he obtained a solution by raising the temperature of the liquid in a Papin's digester. If the heat thus produced was too great, the hair was decomposed, and ammonia, carbonic acid, and an empyreumatic oil formed. Sulphureted hydrogen is always evolved, and its quantity increases with the heat. When hair is thus dissolved in water heated above the boiling point, the solution contains a kind of bituminous oil, which is deposited very slowly. This oil was black when the hair dissolved was black, but yellowish red when red hair was employed.

When the solution is filtered to get rid of this oil, the liquid which passes through is nearly colourless. Copious precipitates are formed in it by the infusion of nutgalls and oxymuriatic acid. Silver is blackened by it, and acetate of lead precipitated brown. Acids render it turbid, but the precipitate is re-dissolved by adding these liquids in excess. Though very much concentrated by evaporation, it does not concrete into a jelly.

Water containing only four per cent. of potash dissolves hair, while hydrosulphuret of ammonia is evolved. If the hair be black, a thick dark-coloured oil, with some sulphur and iron, remains undissolved; if the hair be red, there remains a yellow oil, with some sulphur and an atom or two of iron. When acids are dropt into this solution, they throw down a white matter soluble in an excess of acid.

Sulphuric and muriatic acids become red when first poured on hair, and gradually dissolve it. Nitric acid turns hair yellow and dissolves it, while an oil separates, which is red or black according to the colour of the hair dissolved. The solution yields a great deal of oxalic acid, and contains, besides, bitter principle, iron, and sulphuric acid. Oxymuriatic acid first whitens hair, and then reduces it to a substance of the consistence of turpentine, and partly soluble in alcohol.

When alcohol is digested on black hair, it extracts from it two kinds of oil. The first, which is white, subsides in white shining scales as the liquor cools; the second is obtained by evaporating the alcohol. It has a greyish green colour, and at last becomes solid. From red hair alcohol likewise separates two oils; the first white as from black hair, and the other as red as blood. When the red hair is deprived of this oil, it becomes of a chesnut colour. Hence its red colour is obviously owing to the red oil.

When hair is incinerated, it yields iron and manganese, phosphate, sulphate, and carbonate of lime, muriate of soda, and a considerable portion of silica. The ashes of red hair contain less iron and manganese: those of white hair still less; but in them we find magnesia, which is wanting in the other varieties of hair. The ashes of hair do not exceed 0·015 of the hair.

From the preceding experiments of Vauquelin, we learn that black hair is composed of the nine following substances:

1. An animal matter, constituting the greatest part.
2. A white solid oil, small in quantity.
3. A greyish green oil, more abundant.
4. Iron; state unknown.
5. Oxide of manganese.
6. Phosphate of lime.
7. Carbonate of lime, very scanty.
8. Silica.
9. Sulphur.

The colouring matter of hair appears from Vauquelin's experiments to be an oil. The oil is blackish green in black hair, red in red hair, and white in white hair. Vauquelin supposes that sulphureted iron contributes to the colour of dark hair; and ascribes to the presence of an excess of sulphur the property which white and red hair have of becoming black with the oxides of the white metals. The sudden change of colour in hair from grief, he thinks, is owing to the evolution of an acid.

2. *Feathers* seem to possess nearly the same properties with hair. Mr Hatchett has ascertained that the quill is composed chiefly of coagulated albumen. Though feathers were boiled for a long time in water, Mr Hatchett could observe no traces of gelatine.

HAVING given the preceding account of the solids which compose animal bodies, I proceed next to the fluid which circulates through living bodies, namely *blood;* and to the various *secretions* formed from the blood, either in order to answer some important purpose to the animal, or to be evacuated as useless, that the blood thus purified may be more proper for answering the ends for which it was destined. Many of these substances have been examined with more care by chemists than the animal solids.

SECT. IX. *Of Blood.*

Blood is a well-known fluid which circulates in the veins and arteries of the more perfect animals. It is of a red colour, has a considerable degree of consistency, and an unctuous feel, as if it contained a quantity of soap. Its taste is slightly saline, and it has a peculiar smell.

The specific gravity of human blood is, at a medium, 1·0527.

When blood, after being drawn from an animal, is allowed to remain for some time at rest, it very soon coagulates into a solid mass of the consistence of curdled milk. This mass gradually separates into two parts; one of which is fluid, and is called *serum*; the other, the coagulum, has been called *cruor*, because it alone retains the red colour which distinguishes blood. This separation is very similar to the separation of curdled milk into curds and whey.

1. The serum is of a light greenish yellow colour; it has the taste, smell, and feel of the blood, but its consistence is not so great. Its mean specific gravity is about 1·0287. It converts syrup of violets to a green, and therefore contains an alkali. On examination, Rouelle found that it owes this property to a portion of soda. When heated to the temperature of 156°, the serum coagulates, as Harvey first discovered. It coagulates also when boiling water is mixed with it; but if serum be mixed with six parts of cold water, it does not coagulate by heat. When thus coagulated, it has a greyish white colour, and is not unlike the boiled white of an egg. If the coagulum be cut into small pieces, a muddy fluid may be squeezed from it, which has been termed the *serosity*. After the separation of this fluid, if the residuum be carefully washed in boiling water and examined, it will be found to possess all the properties of coagulated *albumen*. The serum, therefore, contains a considerable proportion of albumen. Hence its coagulation by heat, and the other phenomena which albumen usually exhibits.

If the coagulated serum be heated in a silver vessel, the surface of the silver becomes black, being converted into a sulphuret. Hence it is evident that it contains sulphur; and Proust has ascertained that it is combined with ammonia in the state of a hydrosulphuret.

If serum be mixed with twice its weight of water, and, after coagulation by heat, the albumen be separated by filtration, and the liquid be slowly evaporated till it is considerably concentrated, a number of crystals are deposited when the liquid is left standing in a cool place. These crystals, first examined by Rouelle, consist of carbonate of soda, muriate of soda, besides phosphate of soda and phosphate of lime. The soda exists in the blood in a caustic state, and seems to be combined with the gelatine and albumen. The carbonic acid combines with it during evaporation.

2. The cruor, or *clot* as it is sometimes called, is of a red colour, and possesses considerable consistence. Its mean specific gravity is about 1·245. If this cruor be washed carefully by letting a small jet of water fall upon it till the water runs off colourless, it is partly dissolved, and partly remains upon the searce. Thus it is separated into two portions: namely, 1. A white, solid, elastic substance, which has all the properties of *fibrin;* 2. The portion held in solution by the water, which consists of the colouring matter, not however in a state of purity, for it is impossible to separate the cruor completely from the serum.

Bucquet proved that this watery solution contained albumen and iron. Menghini had ascertained, that if blood be evaporated to dryness by a gentle heat, a quantity of iron may be separated from it by the magnet. The quantity which he obtained was considerable; according to him, the blood of a healthy man contains above two ounces of it. Now, as neither the serum nor the fibrin extracted from the cruor contains iron, it follows of course, that the water holding the colouring matter in solution must contain the whole of that metal.

This watery solution gives a green colour to syrup of violets. When exposed to the air, it gradually deposites flakes, which have the properties of albumen. When heated, a brown-coloured scum gathers on its surface. If it be evaporated to dryness, and then mixed with alcohol, a portion is dissolved, and the alcoholic solution yields by evaporation a residuum, which lathers like soap in water, and tinges vegetable blues green; the acids occasion a precipitate from its solution. This substance is a compound of albumen and soda. Thus we see that the watery solution contains albumen, iron, and soda.

Fourcroy and Vauquelin have ascertained that the iron is combined with phosphoric acid, and in the state of *sub-phosphate* of iron; thus confirming an opinion which had been maintained by Sage, and announced as a fact by Gren.

Such are the properties of blood, as far as they have been hitherto ascertained by experiment. We have seen that it contains the following ingredients:

1. Water
2. Fibrin
3. Albumen
4. Hydrosulph. of ammonia
5. Soda
6. Subphosphate of iron
7. Muriate of soda
8. Phosphate of soda
9. Phosphate of lime

Besides benzoic acid, which has been detected by Proust.

SECT. X. *Of Milk.*

Milk is a fluid secreted by the female of all those animals denominated *mammalia,* and intended evidently for the nourishment of her offspring.

The milk of every animal has certain peculiarities which distinguish it from every other milk. But the animal whose milk is most made use of by man as an article of food, and with which, consequently, we are best acquainted, is the *cow*. Chemists, therefore, have made choice of cow's milk for their experiments.

Milk is an opaque fluid, of a white colour, a slight peculiar smell, and a pleasant sweetish taste. When newly drawn from the cow, it has a taste very different from that which it acquires after it has been kept for some hours. It reddens vegetable blues.

When milk is allowed to remain for some time at rest, there collects on its surface a thick unctuous yellowish coloured substance, known by the name of cream.

After the cream is separated, the milk which remains is much thinner than before, and it has a bluish white colour. If it be heated to the temperature of 100°, and a little *rennet*, which is water digested with the inner coat of a calf's stomach and preserved with salt, be poured into it, coagulation ensues; and if the coagulum be broken, the milk very soon separates into two substances; a solid white part, known by the name of *curd*, and a fluid part called *whey*. Thus we see that milk may be easily separated into three parts; namely, *cream*, *curd*, and *whey*.

1. Cream is of a yellow colour, and its consistence increases gradually by exposure to the atmosphere. In three or four days it becomes so thick that the vessel which contains it may be inverted without risking any loss. In eight or ten days more, its surface is covered over with mucors and byssi, and it has no longer the flavour of cream, but of very fat cheese.

Cream possesses many of the properties of an oil. It is specifically lighter than water; it has an unctuous feel, stains clothes precisely in the manner of oil; and if it be kept fluid, it contracts at last a taste which is very analogous to the rancidity of oils. These properties are sufficient to show us that it contains a quantity of oil; but this oil is combined with a part of the curd, and mixed with some serum. Cream, then, is composed of a peculiar oil, curd, and serum. The oil may be easily obtained separate by agitating the cream for a considerable time. This process, known to every body, is called *churning*. After a certain time, the cream separates into two portions: one fluid, and resembling creamed milk; the other solid, and called *butter*.

Butter is of a yellow colour, possesses the properties of an oil, and mixes readily with other oily bodies. When heated to the temperature of 96° it melts, and becomes transparent; if it be kept for some time melted, some curd and water or whey separate from it, and it assumes exactly the appearance of oil. But this process deprives it in a great measure of its peculiar flavour.

Butter may be obtained by agitating cream newly taken from milk, or even by agitating milk newly drawn from the cow. But it is usual to allow cream to remain for some time before it is churned. Now cream, by standing, acquires a sour taste; butter therefore is commonly made from sour cream. When very sour cream is churned, every one must have perceived, that the butter milk, after the churning, is not nearly so sour as the cream had been. The butter, in all cases, is perfectly sweet; consequently the acid which had been evolved has in a great measure disappeared during the progress of churning. It has been ascertained that cream may be churned, and butter obtained, though the contact of atmospheric air be excluded. On the other hand, it has been affirmed, that when cream is churned in contact with air, it absorbs a considerable quantity of it.

In many cases there is a considerable extrication of gas during the churning of water. From the phenomena, it can scarcely be doubted that this acid is carbonic acid.

2. Curd, which may be separated from creamed *milk* by rennet, has many of the properties of coagulated albumen. It is white and solid; and when all the moisture is squeezed out, it has a good deal of brittleness. It is insoluble in water; but pure alkalies and lime dissolve it readily, especially when assisted by heat; and when fixed alkali is used, a great quantity of ammonia is emitted during the solution. The solution of curd in soda is of a red colour, at least if heat be employed; owing, probably, to the separation of charcoal from the

curd by the action of the alkali. The matter dissolved by the alkali may be separated from it by means of an acid; but it has lost all the properties of curd. It is of a black colour, melts like tallow by the application of heat, leaves oily stains on paper, and never acquires the consistence of curd.

Curd, as is well known, is used in making *cheese;* and the cheese is the better the more it contains of cream, or of that oily matter which constitutes cream. It is well known to cheesemakers, that the goodness of it depends in a great measure on the manner of separating the whey from the curd. If the milk be much heated, the coagulum broken in pieces, and the whey forcibly separated, as is the practice in many parts of Scotland, the cheese is scarce good for any thing; but the whey is delicious, especially the last squeezed out whey, and butter may be obtained from it in considerable quantity:—a full proof that nearly the whole creamy part of the milk has been separated with the whey. Whereas if the milk be not too much heated (about 100° is sufficient), if the coagulum be allowed to remain unbroken, and the whey be separated by very slow and gentle pressure, the cheese is excellent; but the whey is almost transparent, and nearly colourless.

Good cheese melts at a moderate heat; but bad cheese, when heated, dries, curls, and exhibits all the phenomena of burning horn. From this it is evident, that good cheese contains a quantity of the peculiar oil which constitutes the distinguishing characteristic of cream; hence its flavour and smell. Proust has found in cheese an acid which he calls the *caseic* acid, to which he ascribes several of the peculiar properties of cheese.

3. Whey, after being filtered, to separate a quantity of curd which still continues to float through it, is a thin pellucid fluid, of a yellowish green colour and pleasant sweetish taste, in which the flavour of milk may be distinguished. It always contains some curd; but nearly the whole may be se-

parated by keeping the whey for some time boiling; a thick white scum gathers on the surface, which in Scotland is known by the name of *float whey*. When this scum, which consists of the curdy part, is carefully separated, the whey, after being allowed to remain at rest for some hours, to give the remainder of the curd time to precipitate, is decanted off almost as colourless as water, and scarcely any of the peculiar taste of milk can be distinguished in it. If it be now slowly evaporated, it deposites at last a number of white-coloured crystals, which are *sugar of milk*. Toward the end of the evaporation, some crystals of muriate of potash and of muriate of soda make their appearance. According to Scheele, it contains also a little phosphate of lime, which may be precipitated by ammonia.

The recent experiments of Fourcroy and Vauquelin, Thenard, and Bouillon La Grange, have added considerably to our knowledge of the constituents of whey. It always reddens vegetable blues, containing a portion of acetic acid. The lactic acid of Scheele is nothing else than this acid holding an animal matter in solution. It contains likewise some phosphate of magnesia and phosphate of iron, as Fourcroy and Vauquelin have discovered. Sulphate of potash, likewise, and a peculiar extractive matter, have been separated from it.

Thus we see that cow's milk is composed of the following ingredients:

1. Water.
2. Oil.
3. Curd.
4. Extractive.
5. Sugar of milk.
6. Acetic acid.
7. Muriate of soda.
8. Muriate of potash.
9. Sulphate of potash.
10. Phosphate of lime.
11. Phosphate of magnesia.
12. Phosphate of iron.

The milk of all other animals, as far as it has hitherto been examined, consists nearly of the same ingredients: but there is a very great difference in their proportion.

SECT. XI. *Of Saliva.*

The fluid secreted in the mouth, which flows in considerable quantity during a repast, is known by the name of *saliva*.

Saliva is a limpid fluid like water; but much more viscid: it has neither smell nor taste. Its specific gravity, according to Hamberger, is 1·0167; according to Siebold, 1·080. When agitated, it froths like all other adhesive liquids; indeed it is usually mixed with air, and has the appearance of froth.

It neither mixes readily with water nor oil; but by trituration in a mortar it may be so mixed with water as to pass through a filter. It has a great affinity for oxygen, absorbs it readily from the air, and gives it out again to other bodies.

When boiled in water, a few flakes of albumen precipitate. From the experiments of Dr Bostock, we learn that this albumen is not in a state of solution. It is separated by the filter, and subsides of its own accord when the liquid is diluted with water. In his analysis, this coagulated albumen amounted to 0·4 of the solid matter contained in the saliva examined.

When saliva is evaporated, it swells exceedingly, and leaves behind it a thin brown-coloured crust: But if the evaporation be conducted slowly, small cubic crystals of muriate of soda are formed. The viscidity of saliva, the property which it has of absorbing oxygen, and of being inspissated, announce the presence of mucus as a component part. This is fully confirmed by the effect of neutral acetate of lead, which produces a copious precipitate in saliva. Dr Bostock considers the mucus as constituting about one-half of the solid contents of saliva.

When saliva is distilled in a retort, it froths very much: 100 parts yield 80 parts of water nearly pure, then a little carbonate of ammonia, some oil, and an acid, which perhaps is the prussic. The residuum amounts to about 1·56 part, and is composed of muriate of soda, phosphate of soda, and phosphate of lime.

The acids and alcohol inspissate saliva; the alkalies disengage ammonia; oxalic acid precipitates lime; and the nitrates of lead, mercury, and silver, precipitate phosphoric and muriatic acids.

From these facts, it follows that saliva, besides water, which constitutes at least four-fifths of its bulk, contains the following ingredients:

1. Mucilage.
2. Albumen.
3. Muriate of soda.
4. Phosphate of soda.
5. Phosphate of lime.
6. Phosphate of ammonia.

But it cannot be doubted that, like all the other animal fluids, it is liable to many changes from disease, &c. Brugnatelli found the saliva of a patient labouring under an obstinate venereal disease impregnated with oxalic acid.

SECT. XII. *Of Bile.*

Bile is a liquid of a yellowish green colour, an unctuous feel, bitter taste, and peculiar smell, which is secreted by the liver; and in most animals considerable quantities of it are usually found collected in the gall bladder.

1. Ox bile is a liquid of a yellowish green and sometimes of a deep green colour. Its taste is very bitter, but at the same time sweetish. Its smell is feeble, but peculiar and disagreeable. It does not act on vegetable blues. Its consistence varies very much. Sometimes it is a thin mucilage;

sometimes very viscid and glutinous; sometimes it is perfectly transparent, and sometimes it contains a yellow coloured matter which precipitates when the bile is diluted with water.

When an acid is added to bile, even in a minute quantity, it acquires the property of reddening vegetable blues. The addition of a little more acid occasions a precipitate, and sulphuric acid occasions a greater precipitate than any other acid. This precipitate consists of a yellow coloured matter often visible in bile, and which is insoluble in water. It contains also a little resin which gives it a bitter taste. Acids do not throw down the whole resin from bile. Yet if the resin be dissolved in soda, it is readily precipitated by all the acids; a proof that the resin is not kept in solution in bile by soda.

When superacetate of lead is poured into bile a copious white precipitate falls, consisting of the resin combined with the oxide of lead. The superacetate of commerce does not readily throw down the whole resin; but if eight parts of common sugar of lead and one part of litharge be united together by digestion in water, a salt is formed which readily throws down the whole of the resin. If the precipitate be treated with diluted nitric acid the lead is separated, and the resin remains behind in a state of purity. It is a green coloured, bitter tasted substance, possessing most of the properties of resins. It has been already described in the preceding Chapter. One hundred parts of bile contain about three parts of resin.

If acetate of lead be poured into bile thus deprived of its resin by the superacetate, a new and more copious precipitate falls, consisting of the oxide of lead united to a peculiar substance, which gives bile most of its characters. This substance was first described in detail by Thenard, who has given it the name of *picromel*. The compound, consisting of oxide of lead and picromel, is soluble in acetic acid. If a current of sulphureted hydrogen gas be passed through the solution, the lead is separated; and by filtering and evaporating the liquid to dryness, the picromel is obtained in a separate state. When bile, mixed with muriatic acid and filtered, is set aside for some months in an open vessel, I have seen the picromel separate of its own accord. It is a white solid substance in small globules. It has a sweet, and at the same time an acrid taste, and is often somewhat bitter from retaining a portion of the resin. It facilitates the solution of resin in water: three parts of picromel and one part of resin dissolve in water.

By evaporating a quantity of bile to dryness, calcining it, and proceeding in the usual way, Thenard ascertained the proportion of salts which it contained. The following was the result of his analysis of 800 parts of bile.

700·0	water.
24·0	resin.
60·3	picromel.
4·5	yellow matter.
4·0	soda.
2·0	phosphate of soda.
3·2	muriate of soda.
0·8	sulphate of soda.
1·2	phosphate of lime.
	oxide of iron, a trace.
800·0	

2. Such are the properties and the constituents of ox bile, as far as they have been examined by Thenard. From the experiments of the same chemist it appears, that the bile of the calf, the dog, the sheep, and the cat, resemble that of the ox exactly, both in their properties and their constituents.

3. The bile of the sow differs entirely from that of all these animals. It contains neither albumen, nor animal matter, nor picromel, but is merely a soap, as it contains a great quantity of resin and of soda, and is decomposed with facility by all the acids, even by vinegar. It contains traces also of several salts; but Thenard did not ascertain their nature.

4. The bile of the common hen, of the turkey, and the duck, has a good deal of resemblance to that of quadrupeds. But it differs in the following particulars: 1. It contains a considerable quantity of albumen; 2. The picromel has no sensible sweet taste, but is very acrid and bitter; 3. It contains very little soda; 4. The resin is not precipitated by common superacetate of lead; but superacetate, boiled with one-fourth of its weight of litharge, occasions it to precipitate.

5. The bile of the thornback and salmon is yellowish white. When evaporated it leaves a matter which has a very sweet and slightly acrid taste. It appears to contain no resin. The bile of the carp and the eel is very green, very bitter, contains little or no albumen, but yields soda, resin, and a sweet acrid matter similar to that which may be obtained from salmon bile.

6. Human bile differs considerably from that of all other animals examined. Its taste is not very bitter. It is seldom completely liquid, but usually contains some yellow matter suspended in it. When evaporated to dryness it leaves a brown matter amounting to about $\frac{1}{11}$th of the original weight. All the acids decompose human bile, and throw down a copious precipitate consisting of albumen and resin. The following were the proportions of the constituents obtained by Thenard from 1100 parts of human bile:

1000·0 water.

from 2 to 10 yellow insoluble matter.

yellow matter in solution, a trace.

42·0 albumen.
41·0 resin.
5·6 soda.
4·5 phosphate of soda, sulphate of soda, muriate of soda, phosphate of lime, oxide of iron.

SECT. XIII. *Of the Cerumen of the Ear.*

Cerumen is a viscid yellow-coloured liquid secreted by the glands of the auditory canal, which gradually becomes concrete by exposure to the air.

It has an orange-yellow colour and a bitter taste. When slightly heated upon paper, it melts, and stains the paper like an oil; at the same time it emits a slightly aromatic odour. On burning coals it softens, emits a white smoke, which resembles that given out by burning fat; it afterwards melts, swells, becomes dark-coloured, and emits an ammoniacal and empyreumatic odour. A light coal remains behind.

When agitated in water, cerumen forms a kind of emulsion, which soon putrefies, depositing at the same time white flakes.

Alcohol, when assisted by heat, dissolves five-eighths of the cerumen; the three-eighths which remain behind have the properties of albumen, mixed however with a little oily matter. When the alcohol is evaporated, it leaves a deep orange residuum of a very bitter taste, having a smell and a consistence analogous to turpentine. It melts when heated, evaporates in a white smoke without leaving any residuum, and in short resembles very strongly the *resin of bile*. Ether also dissolves this oily body; but it is much less bitter and much lighter coloured. When the albuminous part of cerumen is burnt, it leaves traces of soda and of phosphate of lime. From these facts Vauquelin considers cerumen as composed of the following substances:

1. Albumen.
2. An inspissated oil.
3. A colouring matter.
4. Soda.
5. Phosphate of lime.

SECT. XIV. *Of Tears and Mucus.*

The liquid called tears is transparent and colourless like water; it has scarcely any smell, but its taste is always perceptibly salt. Its specific gravity is somewhat greater than that of distilled water. It gives to paper stained with the juice of the petals of mallows or violet a permanently green colour, and therefore contains a fixed alkali. It unites with water, whether cold or hot, in all proportions. Alkalies unite with it readily, and render it more fluid. The mineral acids produce no apparent change upon it. Exposed to the air, this liquid gradually evaporates, and becomes thicker. When nearly reduced to a state of dryness, a number of cubic crystals form in the midst of a kind of mucilage. These crystals possess the properties of muriate of soda; but they tinge vegetable blues green, and therefore contain an excess of soda. The mucilaginous matter acquires a yellowish colour as it dries.

When alcohol is poured into this liquid, a mucilaginous matter is precipitated in the form of large white flakes. The alcohol leaves behind it, when evaporated, traces of muriate of soda and soda. The residuum which remains behind, when inspissated tears are burnt in the open air, exhibits some traces of phosphate of lime and phosphate of soda.

Thus it appears that tears are composed of the following ingredients:

1. Water.
2. Mucus
3. Muriate of soda.
4. Soda.
5. Phosphate of lime.
6. Phosphate of soda.

The saline parts amount only to about 0·01 of the whole, or probably not so much.

2. The mucus of the nose has also been examined by Fourcroy and Vauquelin. They found it composed of precisely the same ingredients with the tears. As this fluid is more exposed to the action of the air than the tears, in most cases its mucilage has undergone less or more of that change which is the consequence of the absorption of oxygen. Hence the reason of the greater viscidity and consistence of the mucus of the nose; hence also the great consistence which it acquires during colds, where the action of the atmosphere is assisted by the increased action of the parts.

3. As to the mucus which lubricates the alimentary canal, the trachea, the bronchiæ, the urethra, and all the different cavities of the body, nobody has hitherto subjected it to analysis, because it cannot be obtained in sufficient quantity. It is viscid, and no doubt contains a mucilaginous substance, similar to that contained in the saliva, the tears, and the mucus of the nose; as, like these liquids, it is liable to become much more thick by exposure to the air.

SECT. XV. *Liquor of the Pericardium.*

This is is a liquor which lubricates the heart. It has been lately examined by Dr Bostock, having been obtained from the pericardium of a boy who had died suddenly.

It had the colour and appearance of the serum of the blood. Evaporated to dryness, it left a residue amounting to $\frac{1}{13}$th of its weight. When exposed to the heat of boiling water, it became opaque and thready. It was copiously precipitated by oxymuriate of mercury before boiling; but when boiled, evaporated to dryness, and re-dissolved, the solution was not affected by oxymuriate of mercury. These experiments show us that it contained albumen. When saturated with oxymuriate of mercury, infusion of galls produced no effect, indicating the absence of gelatine. It was copiously precipitated by neutral acetate of lead, even after being boiled to dryness and the residue re-dissolved in water. Nitrate of silver indicated the presence of muriatic acid. Dr Bostock, from his experiments, considers it composed of

Water	92·0
Albumen	5·5
Mucus	2·0
Muriate of soda	0·5
	100·0

SECT. XVI. *Of the Humours of the Eye.*

The eye is one of the most delicate and complicated organs in the body; at the same time its structure, and the uses of its parts, are better understood than almost any of the other instruments of sensation. It is composed of several concentric coats, which have not been chemically examined; but, from the experiments of Hatchett on similar substances, we may consider it as probable that they possess the properties of coagulated albumen. The internal part of the eye is chiefly filled with three transparent substances, which have been called *humours* by anatomists; namely, 1. The *aqueous humour*, immediately behind the cornea; 2. The *crystalline humour* or *lense;* and, 3. The *vitreous humour*, behind the lense, and occupying the greatest part of the eye.

1. The aqueous humour of the eye of the sheep is a clear transparent liquid like water, which has very little smell or taste when fresh. Its specific gravity is 1·0090 at the temperature of 60°. It appears to be water slightly impregnated with the following substances:

1. Albumen. 2. Gelatine. 3. Muriate of soda.

2. The vitreous matter possesses the very same properties as the aqueous; even its specific gravity is the same, or only a very little greater.

3. The crystalline lense is solid: densest in the centre, and becoming less solid towards the circumference. It is composed of concentric coats, and is transparent. Its specific gravity is 1·1000. When fresh it has little taste. It putrefies very rapidly.

It is almost completely soluble in water. The solution is partly coagulated by heat, and gives a copious precipitate with tannin both before the coagulation and after it. It gives no traces of muriatic acid. Hence it is composed of albumen and gelatine united to water. According to Nicholas, the quantity of gelatine diminishes as we approach the centre of the lense, where it is very small. He detected phosphate of lime likewise in every part of the lense.

The humours of the human eye are composed of the same ingredients as those of the sheep; the only perceptible difference consists in their specific gravity. The specific gravity of the human aqueous and vitreous humours is 1·0053; that of the crystalline 1·0790.

The humours of the eyes of oxen resemble those of the sheep in their composition. The specific gravity of the aqueous and vitreous humours is 1·0088; that of the crystalline 1·0765.

SECT. XVII. *Of Sinovia.*

Within the capsular ligament of the different joints of the body there is contained a peculiar liquid, intended evidently to lubricate the parts, and to facilitate their motion. This liquid is known among anatomists by the name of *sinovia.*

The sinovia of the ox, when it has just flowed from the joint, is a viscid semitransparent fluid, of a greenish white colour, and a smell not unlike frog-spawn. It very soon acquires the consistence of jelly; and this happens equally whether it be kept in a cold or a hot temperature, whether it be exposed to the air or excluded from it. This consistence does not continue long; the sinovia soon recovers again its fluidity, and at the same time deposites a thready-like matter.

Sinovia mixes readily with water, and imparts to that liquid a great deal of viscidity. The mixture froths when agitated; becomes milky when boiled, and deposites some pellicles on the sides of the dish; but its viscidity is not diminished.

When alcohol is poured into sinovia, a white substance precipitates, which has all the properties of albumen. One hundred parts of sinovia contain 4·52 of albumen. The liquid still continues as viscid as ever; but if acetic acid be poured into it, the viscidity disappears altogether, the liquid becomes transparent, and deposites a quantity of matter in white threads, which possesses the following properties: 1. It has the colour, smell, taste, and elasticity of vegetable gluten. 2. It is soluble in concentrated acids and pure alkalies. 3. It is soluble in cold water; the solution froths. Acids and alcohol precipitate the fibrous matter in flakes. One hundred parts of sinovia contain 11·86 of this matter.

Margueron found that 100 parts of sinovia contained about 0·71 of soda.

When sinovia is exposed to a dry atmosphere, it gradually evaporates, and a scaly residuum remains, in which cubic crystals, and a white saline efflorescence are apparent. The cubic crystals are muriate of soda. One hundred parts of sinovia contain 1·75 of this salt. The saline efflorescence is carbonate of soda.

From the analysis of Mr Margueron, it appears that sinovia is composed of the following ingredients:

11·86	fibrous matter.
4·52	albumen.
1·75	muriate of soda.
·71	soda.
·70	phosphate of lime.
80·46	water.
100·00	

Sect. XVIII. *Of Semen.*

The peculiar liquid secreted in the testes of males, and destined for the impregnation of females, is known by the name of *semen*.

Semen, when newly ejected, is evidently a mixture of two different substances: the one fluid and milky, which is supposed to be secreted by the prostate gland; the other, which is considered as the true secretion of the testes, is a thick mucilaginous substance, in which numerous white shining filaments may be discovered. It has a slight disagreeable odour, an acrid irritating taste, and its specific gravity is greater than that of water. When rubbed in a mortar it becomes frothy, and of the consistence of pomatum, in consequence of its enveloping a great number of air-bubbles. It converts paper stained with the blossoms of mallows or violets to a green colour, and consequently contains an alkali.

As the liquid cools, the mucilaginous part becomes transparent, and acquires greater consistency; but in about twenty minutes after its emission, the whole becomes perfectly liquid. This liquefaction is not owing to the absorption of moisture from the air, for it loses instead of acquiring weight during its exposure to the atmosphere; nor is it owing to the action of the air, for it takes place equally in close vessels.

When oxymuriatic acid is poured into semen, a number of white flakes precipitate, and the acid loses its peculiar odour. These flakes are insoluble in water, and even in acids. If the quantity of acid be sufficient, the semen acquires a yellow colour. Thus it appears that semen contains a mucilaginous substance analogous to that of the tears, which coagulates by absorbing oxygen. Mr Vauquelin obtained from 100 parts of semen six parts of this mucilage.

When semen is exposed to the air about the temperature of 60°, it becomes gradually covered with a transparent pellicle, and in three or four days deposites small transparent crystals, often crossing each other in such a manner as to represent the spokes of a wheel. These crystals, when viewed through a microscope, appear to be four-sided prisms, terminated by very long four-sided pyramids. They may be separated by diluting the liquid with water, and decanting it off. They have all the properties of phosphate of lime. If, after the appearance of these crystals, the semen be still allowed to remain exposed to the atmosphere, the pellicle on its surface gradually thickens, and a number of white round bodies appear on different parts of it. These bodies also are phosphate of lime, prevented from crystallizing regularly by the too rapid abstraction of moisture. Mr Vauquelin found that 100 parts of semen contain three parts of phosphate of lime. If, at this period of the evaporation, the air becomes moist, other crystals appear in the semen, which have the properties of carbonate of soda. The evaporation does not go on to complete exsiccation, unless at the temperature of 77°, and when the air is very dry. When all the moisture is evaporated, the semen has lost 0·9 of its weight; the residuum is semitransparent like horn, and brittle.

Thus it appears that semen is composed of the following ingredients:

90 water.
6 mucilage.
3 phosphate of lime.
1 soda.

100

SECT. XIX. *Of Animal Poisons.*

Several animals are furnished with liquid juices of a poisonous nature, which, when poured into fresh wounds, occasion the disease or death of the wounded animal. Serpents, bees, scorpions, spiders, are well known examples of such animals. The chemical properties of these poisonous juices deserve peculiar attention; because it is only from such an investigation that we can hope to explain the fatal changes which they induce on the animal economy, or to discover an antidote sufficiently powerful to counteract their baneful influence. Unfortunately the task is difficult, and perhaps surpasses our chemical powers. For the progress already made in the investigation, we are indebted almost entirely to the labours of Fontana.

1. The poison of the viper is a yellow liquid, which lodges in two small vesicles in the animal's mouth. These communicate by a tube with the crooked fangs, which are hollow, and terminate in a small cavity. When the animal bites, the vesicles are squeezed, and the poison is forced through the fangs into the wound.

This poisonous juice occasions the fatal effects of the viper's bite. It has a yellow colour, has no taste; but when applied to the tongue occasions numbness. It has the appearance of oil before the microscope, but it unites readily with water. It produces no change on vegetable blues.

When exposed to the open air, the watery part gradually evaporates, and a yellowish-brown substance remains, which has the appearance of gum arabic. In this state it feels viscid like gum between the teeth; it dissolves readily in water, but not in alcohol; and alcohol throws it down in a white powder from water. Neither acids nor alkalies have much effect upon it. It does not unite with volatile oils nor sulphuret of potash. When heated it does not melt, but swells, and does not inflame till it has become black. These properties are similar to the properties of gum, and indicate the gummy nature of this poisonous substance. Fontana made a set of experiments on the dry poison of the viper, and a similar set on gum arabic, and obtained the same results.

From the late observations of Dr Russel, there is reason to believe that the poisonous juices of the other serpents are similar in their properties to those of the viper.

This striking resemblance between gums and the poison of the viper, two substances of so opposite a nature in their effects upon the living body, is a humiliating proof of the small progress we have made in the chemical knowledge of these intricate substances. The poison of the viper, and of serpents in general, is most hurtful when mixed with the blood. Taken into the stomach it kills if the quantity be considerable. Fontana has ascertained that its fatal effects are proportional to its quantity, compared with the quantity of the blood. Hence the danger diminishes as the size of the animal increases. Small birds and quadrupeds die immediately when they are bitten by a viper; but to a full-sized man the bite seldom proves fatal.

Ammonia has been proposed as an antidote to the bite of the viper. It was introduced in consequence of the theory of Dr Mead, that the poison was of an acid nature. The numerous trials of that medicine by Fontana robbed it of all its celebrity; but it has been lately revived and recommended by Dr Ramsay as a certain cure for the bite of the rattlesnake.

2. The venom of the bee and the wasp is also a liquid contained in a small vesicle forced through the hollow tube of the sting into the wound inflicted by that instrument. From the experiments of Fontana, we learn that it bears a striking resemblance to the poison of the viper. That of the bee is much longer in drying when exposed to the air than the venom of the wasp.

3. The poison of the scorpion resembles that of the viper also. But its taste is hot and acrid, which is the case also with the venom of the bee and the wasp.

4. No experiments upon which we can rely have been made upon the poison of the spider tribe. From the rapidity with which these animals destroy their prey, and even one another, we cannot doubt that their poison is sufficiently virulent.

SECT. XX. *Of Sweat.*

A quantity of matter is constantly emitted from the skin; this matter is invisible, and is distinguished by the name of *perspiration*. Several experiments were made by Lavoisier and Seguin to ascertain its amount. Mr Cruickshanks made numerous trials to determine its nature, and it has been lately subjected to a chemical examination by Thenard.

1. Mr Cruickshanks put his hand into a glass vessel, and luted its mouth at his wrist by means of a bladder. The interior surface of the vessel became gradually dim, and drops of water trickled down. By keeping his hand in this manner for an hour, he collected 30 grains of a liquid, which possessed all the properties of pure water. On repeating the same experiment at nine in the evening (thermometer 62°), he collected only 12 grains. The mean of these is 21 grains.

But as the hand is more exposed than the trunk of the body, it is reasonable to suppose, that the perspiration from it is greater than that from the hand. Let us therefore take 30 grains per hour as the mean; and let us suppose, with Mr Cruickshanks, that the hand is $\frac{1}{60}$th of the surface of the body: The perspiration in an hour would amount to 1880 grains, and in 24 hours to 43,200 grains, or seven pounds six ounces troy. This is almost double of the quantity ascertained by Lavoisier and Seguin. Hence we may conclude that more matter is perspired through the hand than the other parts of the body, provided Mr Cruickshanks's estimate of the ratio between the surface of the hand and body be not erroneous.

He repeated the experiment again after hard exercise, and collected in an hour 48 grains of water. He found also, that this aqueous vapour pervaded his stocking without difficulty; and that it made its way through a shamoy leather glove, and even through a leather boot, though in a much smaller quantity than when the leg wanted that covering.

2. Besides water, it cannot be doubted that *carbon* is also emitted from the skin; but in what state, the experiments hitherto made do not enable us to decide. Mr Cruickshanks found that the air of the glass vessel in which his hand and foot had been confined for an hour contained carbonic acid gas; for a candle burned dimly in it, and it rendered lime-water turbid.

3. Besides water and carbon, or carbonic acid gas, the skin emits also a particular odorous substance. That every animal has a peculiar smell, is well known: the dog can discover his master, and even trace him to a distance, by the scent. A dog, chained some hours after his master had set out on a journey of some hundred miles, followed his footsteps by the smell, and found him on the third day in the midst of a crowd. But it is needless to multiply instances of this fact; they are too well known to every one. Now

this smell must be owing to some peculiar matter which is constantly emitted; and this matter must differ somewhat either in quantity or some other property, as we see that the dog easily distinguishes the individual by means of it. Mr Cruickshanks has made it probable that this matter is an oily substance; or at least that there is an oily substance emitted by the skin. He wore repeatedly, night and day for a month, the same vest of fleecy hosiery during the hottest part of the summer. At the end of this time he always found an oily substance accumulated in considerable masses on the nap of the inner surface of the vest, in the form of black tears. When rubbed on paper, it makes it transparent, and hardens on it like grease. It burns with a white flame, and leaves behind it a charry residuum.

4. Berthollet has observed the perspiration acid; and he has concluded that the acid which is present is the phosphoric: but that has not been proved. Indeed the late experiments of Thenard have proved that the acid in *perspired matter* is not the phosphoric; but the acetic. He employed the method practised by Mr Cruickshanks to collect this matter. Different persons wore clean flannel waistcoats next their skin for ten days, the waistcoats had been first washed with soap, then in pure water, then in water acidulated with muriatic acid, and lastly in a great quantity of pure water. He steeped the waistcoats in hot distilled water, and thus separated from them the perspired matter. The liquid was put into a retort, and concentrated to the consistence of a syrup. The liquid which came over had a disagreeable smell, and reddened infusion of litmus. Kept in an open vessel it retained its transparency, but lost its odour. The residue in the retort had no smell. It was strongly acid, and tasted distinctly of common salt, while at the same time an acrid and hot flavour could be distinguished. When evaporated to dryness and strongly heated, the acid which it con-

tained was dissipated or destroyed, and the residue consisted of common salt, charcoal, and minute traces of phosphate of lime, and oxide of iron. The same destruction of the acid took place if it was previously saturated with potash before it was heated to redness, and in that case the potash was converted into a carbonate. When saturated with an alkali, and distilled along with phosphoric acid, it yielded an acid which possessed all the characters of the acetic.

5. The small quantity of animal matter which Thenard found in the perspired matter, possessed characters which induced him to consider it as similar to gelatine in its nature.

SECT. XX.I—*Of Urine.*

Fresh urine differs considerably in its appearance according to the state of the person and the time at which it is voided. In general, healthy urine is a transparent liquid of a light amber colour, an aromatic odour resembling that of violets, and a disagreeable bitter taste. Its specific gravity varies, according to Mr Cruickshanks, from 1·005 to 1·033. When it cools, the aromatic smell leaves it, and is suceeeded by another, well known by the name of *urinous smell.*

1. Urine reddens paper stained with turnsole and with the juice of radishes, and therefore contains an acid. This acid has been generally considered as the phosphoric; but Thenard has shown that it is in reality the acetic.

2. If a solution of ammonia be poured into fresh urine, a white powder precipitates, which has the properties of phosphate of lime.

3. If the phosphate of lime precipated from urine be examined, a little magnesia will be found mixed with it. Fourcroy and Vauquelin have ascertained that this is owing to a little phosphate of magnesia which urine contains, and

which is decomposed by the alkali of lime employed to precipitate the phosphate of lime.

4. Proust informs us that carbonic acid exists in urine, and that its separation occasions the froth which appears during the evaporation of urine.

5. Proust has observed, that urine kept in new casks deposits small crystals which effloresce in the air and fall to powder. These crystals possess the properties of the carbonate of lime.

6. When fresh urine cools, it often lets fall a brick-coloured precipitate, which Scheele first ascertained to be crystals of uric acid. All urine contains this acid, even when no sensible precipitate appears when it cools.

7. During intermitting fevers, and especially during diseases of the liver, a copious sediment of a brick-red colour is deposited from urine. This sediment contains the rosacic acid of Proust.

8. If fresh urine be evaporated to the consistence of a syrup, and muriatic acid be then poured into it, a precipitate appears which possesses the properties of benzoic acid.

9. When an infusion of tannin is dropt into urine, a white precipitate appears, having the properties of the combination of tannin and albumen or gelatine. Their quantity in healthy urine is very small, often indeed not sensible. Cruickshanks found that the precipitate afforded by tannin in healthy urine amounted to $\frac{1}{240}$th part of the weight of the urine.

10. If urine be evaporated by a slow fire to the consistence of a thick syrup, it assumes a deep brown colour, and exhales a fetid ammoniacal odour. When allowed to cool, it concretes into a mass of crystals, composed of all the component parts of urine. If four times its weight of alcohol poured into this mass, at intervals, and a slight heat be plied, the greatest part of it is dissolved. The alcohol

which has acquired a brown colour, is to be decanted off, and distilled in a retort in a sand heat, till the mixture has boiled for some time, and acquired the consistence of a syrup. By this time the whole of the alcohol has passed off, and the matter, on cooling, crystallizes in quadrangular plates which intersect each other. This substance is *urea,* which composes $\frac{9}{20}$ths of the urine, provided the watery part be excluded. To this substance the taste and smell of urine are owing. It is a substance which characterizes urine, and constitutes it what it is, and to which the greater part of the very singular phenomena of urine are to be ascribed.

11. According to Fourcroy and Vauquelin, the colour of urine depends upon the urea: the greater the proportion of urea, the deeper the colour. But Proust has detected a resinous matter in urine similar to the resin of bile; and to this substance he ascribes the colour of urine.

12. If urine be slowly evaporated to the consistence of a syrup, a number of crystals make their appearance on its surface; these possess the properties of the muriate of soda.

13. The saline residuum which remains after the separation of urea from crystallized urine by means of alcohol has been long known by the names of *fusible salt of urine* and *microcosmic salt.*

When these salts are examined, they are found to have the properties of phosphates. The rhomboidal prisms consist of phosphate of ammonia united to a little phosphate of soda; the rectangular tables, on the contrary, are phosphate of soda united to a small quantity of phosphate of ammonia. Urine, then, contains phosphate of soda and phosphate of ammonia.

14. When urine is cautiously evaporated, a few cubic crystals are often deposited among the other salts; these crystals have the properties of muriate of ammonia.

15. When urine is boiled in a silver bason, it blackens the bason; and if the quantity of urine be large, small crusts of sulphuret of silver may be detached. Hence we see that urine contains sulphur.

Urine, then, contains the following substances:

1. Water.
2. Acetic acid.
3. Phosphate of lime.
4. Phosphate of magnesia.
5. Carbonic acid.
6. Carbonate of lime
7. Uric acid.
8. Rosacic acid,
9. Benzoic acid.
10. Albumen.
11. Urea.
12. Resin.
13. Muriate of soda.
14. Phosphate of soda.
15. Phosphate of ammonia.
16. Muriate of ammonia.
17. Sulphur.

These are the only substances which are constantly found in healthy urine; but it contains also occasionally other substances. Very often muriate of potash may be distinguished among the crystals which form during its evaporation. The presence of this salt may always be detected by dropping cautiously some tartaric acid into urine. If it contains muriate of potash, there will precipitate a little tartar, which may be easily recognized by its properties.

Urine sometimes also contains sulphate of soda, and even sulphate of lime. The presence of these salts may be ascertained by pouring into urine a solution of muriate of barytes; a copious white precipitate appears, consisting of the barytes combined with phosphoric acid, and with sulphuric acid, if any be present. This precipitate must be treated with a sufficient quantity of muriatic acid. The phosphate of barytes is dissolved, but the sulphate of barytes remains unaltered.

SECT. XXII.—*Of Morbid Concretions.*

Hard substances occasionally make their appearance in different parts of the animal body, both in the solids and the cavities destined to contain the fluids. In the first case they are denominated *concretions* or *ossifications*; in the second *calculi*. Their formation is an irregularity in the animal œconomy, and they often produce the most excruciating diseases. They may be divided into five classes; namely, 1. Ossifications; 2. Intestinal concretions; 3. Biliary calculi; 4. Urinary calculi; 5. Gouty calculi.

1. *Ossifications.*

Under this name may be comprehended all the concretions which make their appearance in the solid parts of the animal body. The following are the most remarkable of these:

1. Small concretions sometimes form in the pineal gland. They consist of phosphate of lime.

2. Small concretions sometimes form in the salivary glands. These likewise consist of phosphate of lime.

3. Pulmonary concretions are occasionally coughed up by consumptive patients. They consist sometimes of phosphate of lime, sometimes of carbonate of lime, and sometimes of a mixture of both.

4. Hepatic concretions are composed of phosphate of lime, and a tough animal membrane.

5. The concretions which sometimes form in the prostate-gland are composed of phosphate of lime.

2. *Intestinal Concretions.*

Concretions sometimes form in the stomach and intestines chiefly of the inferior animals. Some of these have been celebrated under the name of *bezoars* for their medical virtue. A great many of them have been analyzed, and no fewer than eight species have been ascertained.

The first species consists of concretions composed of superphosphate of lime, the second of phosphate of magnesia, the third of ammonio-phosphate of magnesia; the fourth of the yellow matter of bile; the fifth of a green-coloured resinous matter; the sixth of small fragments of the *boletus igniarius*; the seventh of balls of hair felted together, and the 8th of woody fibre.

3. *Biliary Calculi.*

Hard bodies sometimes form in the gall bladder and gall ducts, and occasion painful diseases. Four kinds of these calculi have been distinguished; the first kind is composed of a matter resembling spermaceti in appearance, soluble in hot alcohol, and crystallizing as the alcohol cools. This matter has been called *adiposire.* The second kind are angular, because a number of them exist in the gall bladder together. They are composed of adiposire, with a thin external crust of yellow matter of bile. The third kind are of a brown colour, and are supposed to be composed of the altered yellow matter of bile. The gall-stones of oxen usually are of this kind. The fourth kind does not flame, but gradually waste away at a red heat.

4. *Urinary Calculi.*

It is well known that concretions not unfrequently form in the urinary bladder, and occasion one of the most dismal diseases to which the human species is liable. These bodies have been carefully and repeatedly examined by modern chemists, who have found them to be very various in their composition. No less than nine distinct substances have been found These being mixed in different proportions, occasion great variation in the composition of the calculi. The following are the substances:

1. Uric acid.
2. Phosphate of lime.
3. Phosphate of magnesia-and-ammonia,
4. Oxalate of lime.
5. Muriate of ammonia.
6. Magnesia.
7. Phosphate of iron.
8. Silica.
9. Urea.

The four first of these constitute by far the most common and abundant ingredients of urinary calculi.

5. *Gouty Concretions.*

It is well known that concretions occasionally make their appearance in joints long subject to the gout. These concretions, from their colour and softness, are usually distinguished by the name of chalk-stones. They are usually small, though they have been observed of the size of an egg. All of them hitherto examined have been found composed of uric acid and soda, so that they consist of the salt called urate of soda.

BOOK III.

OF AFFINITY.

Having taken a view of the different substances which constitute the objects of chemistry, it remains for us to make a few remarks on the force by which different bodies are united together, and kept in combination. This force has received the name of *affinity*.

All the [illegible] bodies which constitute the solar system are urged towards [illegible], a force which preserves them in their orbits and regulates their motions. This force has received the name of *attraction*. Newton demonstrated that this force is the same with *gravitation*, or the force by which a heavy body is urged towards the earth.

When two bodies are brought within a certain distance, they adhere together, and require a considerable force to separate them. Hence it appears that bodies are not only attracted towards the planetary bodies, but towards each other. In all cases we find the particles of matter united together in masses, differing indeed in magnitude, but containing all of them a considerable number of particles. These particles remain united, and cannot be separated without the application of a considerable force.

Thus we see that there is a certain unknown force which urges bodies towards each other; a force which acts not only upon large masses of matter, but upon the particles of which bodies are composed. Attraction, therefore, as far as we know, extends to all matter, and exists mutually between all matter.

The change which attraction produces on bodies is a diminution of their distance. Now the distances of bodies from each other are of two kinds, either too small to be perceived by our senses, or great enough to be easily perceived and estimated. Hence the attractions of bodies as far as regards us naturally divide themselves into two classes. 1. Those which act at sensible distances from each other. 2. Those which act at insensible distances. It is to the second of these attractions that the term *chemical affinity* has been given.

Chemical affinity then is the attraction which exists between the particles of bodies which urges them towards each ot[illegible] and keeps them united. Now the particles of matter are of two kinds, either *homog[illegible] h[illegible]eneous*. By homogeneous particles are meant the [illegible] which compose the same body; by heterogeneous those which compose different bodies. Thus the particles of iron are homogeneous; but a particle of iron and a particle of lead are heterogeneous.

Homogeneous affinity urges the homogeneous particles towards each other, and keeps them united. It is usually denoted by the term *cohesion*, and sometimes by *adhesion* when the surfaces of bodies only are referred to.

Heterogeneous affinity urges heterogeneous particles towards each other, and keeps them at insensible distances, and of course is the cause of the formation of new integrant particles composed of a certain number of heterogeneous particles.

Affinity, like sensible attraction, varies with the mass, and the distance of the attracting bodies; but the rate at which it varies remains still unknown. The characteristic marks of affinity may be reduced to the three following.

1. It acts only at insensible distances, and of course affects only the particles of bodies.

2. Its force is always the same in the same particles, but it is different in different particles.

3. This difference is modified considerably by the mass. Thus, though A have a greater affinity for C than B has, if the mass of B be considerably increased while that of A remains unchanged, B becomes capable of taking a part of C from A. Let us now take a particular view of gases, liquids and solids, that we may ascertain in what way they unite, and how far their combinations are influenced by the state of the bodies themselves.

CHAP. I.

OF GASES.

Gases are elastic fluids, which yield to the smallest impression, and have their parts easily moved. Their elasticity varies with the pressure, and hence it follows that their particles mutually repel inversely as the distances of their centres from each other. The gaseous bodies at present known (including some vapours) amount to 23. The following table exhibits their names and their specific gravity.

Gases.	*Sp. gravity.*
Air	1·000
Oxymuriatic acid	2·766
Nitric acid	2·427
Sulphurous acid	2·265
Vapour of ether	2·250
Vapour of alcohol	2·100
Muriatic acid	1·929

Gazes.	*Sp. gravity.*
Hyperoxymuriatic acid	——
Fluoric acid	——
Nitrous oxide	1·603
Carbonic acid	1·500
Sulphureted hydrogen	1·106 1·236
Oxygen	1·093
Nitrous gas	1·094
Azote	0·978
Carbonic oxide	0·956
Olefiant gas	0·909
Steam	0·700
Ammonia	0·600
Carbureted hydrogen	0·600
Arsenical hydrogen	0·529
Phosphureted hydrogen	——
Prussic acid	——
Hydrogen	0·084

The gases usually contain water. This liquid in most of them is in the state of vapour, and only loosely united. Hence it may be separated by cold or by substances which have a strong affinity for water, as sulphuric acid, dry muriate of lime, and the dry fixed alkalies. From the experiments of Saussure we learn, that a hundred cubic inches of air saturated with moisture at the temperature of 57° contain 0.35 of a grain troy of moisture. But muriatic acid contains at least one-fourth of its weight of water in a state of intimate combination, from which it cannot be deprived without losing its elastic form.

When gaseous bodies are brought into contact with each other, they mix equably, how much soever they differ in specific gravity, and when once mixed, they never after separate. By this mixture, neither the bulk nor the specific gravity of the gaseous bodies is altered. This mutual mixture seems to be analogous to what happens when liquids are mixed together, and seems explicable in the same way. It seems to be owing to a weak attraction which exists between the particles of all gaseous bodies. Mr Dalton affirms, that it is owing entirely to the difference between the size of the particles of different gases.

Several gases have the property of uniting intimately with each other, and of forming new products possessing peculiar properties. The following table exhibits a view of those that unite upon simple mixture with the products which they form.

	Products.
Oxygen with nitrous gas	Nitrous acid. Nitric acid.
Ammonia with vapour	Liquid ammonia.
muriatic acid	Muriate of ammonia.
fluoric acid	Fluate of ammonia.
carbonic acid	Carbonate of ammonia.
sulphurous acid	Sulphite of ammonia.
sulphureted hydrogen	Hydrosulphuret of ammonia.

The following are the gases which combine only in particular circumstances with the products which they form:

	Products.
Oxygen with hydrogen	Water.
carbonic oxide	Carbonic acid.
azote	Nitric acid.
muriatic acid	Oxymuriatic acid.
oxymuriatic acid	Hyperoxymuriatic acid.
sulphurous acid	Sulphuric acid.
nitrous oxide	Nitric acid.

The combination of the first two sets is produced by combustion, and may be accomplished either by a red heat or by the electric spark. Oxygen and azote unite slowly by means of electric sparks, but without combustion. Little is known of the way in which the remaining sets combine.

From the experiments hitherto made it follows, that when gaseous bodies unite, they unite either in equal bulks of each, or two or three parts by bulk of one, unite with one part by bulk of the other. The following table exhibits a view of the proportions of the different constituents by bulk of various compounds formed by the union of elastic fluids.

Compounds.	*Constituents by bulk.*	
Muriate of ammonia . .	100 ammoniacal .	100 muriatic acid gas
Carbonate of ammonia .	100 ditto	100 carbonic acid gas
Subcarbonate of ammonia	100 ditto	50 ditto
Water	100 hydrogen gas .	50 oxygen gas
Nitrous oxide	100 azotic gas . . .	50 ditto
Nitrous gas	100 ditto	100 ditto
Nitric acid	100 ditto	200 ditto
Nitric acid	200 nitrous gas . .	100 ditto
Nitrous acid	300 ditto	100 ditto
Ammonia	100 azotic gas . .	300 hydrogen
Sulphuric acid	100 sulphurous acid	50 oxygen
Oxymuriatic acid . . .	300 muriatic acid .	100 ditto
Carbonic acid	100 carbonic oxide .	50 ditto

Some gases, when mixed together, have the property of mutually decomposing each other. The following is a list of these gases.

Oxygen . . with phosphureted hydrogen
Oxymuriatic acid with ammonia
phosphureted hydrogen
hydrogen
carbureted hydrogen
carbonic oxide
olefiant gas
sulphureted hydrogen
sulphurous acid
nitrous gas
Sulphureted hydrogen with nitrous gas
sulphurous acid

Many gases decompose each other by combustion produced either by electric sparks, or by a red hot body. The following are the principal of these gases.

Oxygen with	sulphureted hydrogen
	carbureted hydrogen
	olefiant gas
	vapour of ether
	————alcohol
Nitrous oxide with	hydrogen
	phosphureted hydrogen
	sulphureted hydrogen
	carbonic oxide
	carbureted hydrogen
	olefiant gas
	vapour of ether
	————alcohol
Nitrous gas with	hydrogen
	sulphurous acid
Hydrogen with	sulphurous acid
	carbonic acid
Vapour of water with	carbureted hydrogen
	olefiant gas
	muriatic acid

Water absorbs a certain portion of all the gases. Some of them are absorbed only in small quantity by that liquid, others in large quantity. The following table exhibits the bulk of each gas absorbed by 100 parts of water freed from air by boiling, as determined by the experiments of Dr Henry and Mr Dalton.

Gases.	*Absorption according to*	
	Henry.	Dalton.
Carbonic acid . .	108	100
Sulphureted hydrogen	106	100
Nitrous oxide . .	86	100
Olefiant gas . - -	——	12·5
Nitrous gas . . .	5	3·7
Oxygen gas . . .	3·7	3·7
Phosphuretedhydrogen	2·14	
Carbureted hydrogen	1·4	3·7
Azotic gas . . .	1·53	1·56
Hydrogen . . .	1·61	1·56
Carbonic oxide . .	2·01	1·56

Dr Henry's numbers are the result of experiment: Mr Dalton's of experiment modified a little by a happy generalization. He conceives that the degree of the absorption of each of the four sets into which the gases are divided by the horizontal lines in the preceding table may be represented as follows:

First set. Water absorbs its own bulk = $\frac{1}{1^3}$

Second set ———— $\frac{1}{8}$th its bulk = $\frac{1}{2^3}$

Third set ———— $\frac{1}{27}$ ———— = $\frac{1}{3^3}$

Fourth set ———— $\frac{1}{65}$ ———— = $\frac{1}{4^3}$

From this generalization, which holds at least very nearly, it follows that the density of the gases, after absorption, is either the same as before it, or at least some submultiple of it, and the distance between their particles is either the same as before, or twice, thrice, or four times as great.

Dr Henry has shown, that whatever be the density of the gas, the bulk of it absorbed is always the same. If carbonic acid gas be reduced by pressure to twice the usual density, water still continues to absorb its own bulk of it. Hence by increasing the pressure, water may be made to absorb any *quantity* of a gas whatever.

The gases still retain their elasticity after they have been absorbed by water, accordingly they make their escape if the water be placed under the exhausted receiver of an air pump.

The proportion of a gas absorbed by water depends very much upon its purity. Thus water absorbs its own bulk of pure carbonic acid gas; but if the carbonic acid gas be mixed with common air, the proportion of it absorbed is much diminished. Water impregnated with a gas must be in contact with a portion of the very gas absorbed, otherwise that gas soon makes its escape altogether.

As the temperature increases, the absorbability of the gases by water diminishes, no doubt in consequence of the increased elasticity of the gases.

This absorption of the gases by water is probably the consequence of an affinity between them and that liquid. Hence the determinate proportion of each absorbed, and most of the other phenomena, admit of an easy explanation.

The alkaline and acid gases are very absorbable by water, and of course are acted on by a strong affinity. The following table exhibits a view of the bulk of each gas absorbed by one measure of water.

Oxymuriatic acid . .	1·5 +
Sulphurous acid . .	33
Fluoric acid . . .	175 +
Muriatic acid . . .	516
Ammoniacal gas . .	780

When a cubic inch of water is saturated with these gases, its bulk increases. The following table exhibits the bulk of water when thus saturated, supposing the original bulk to ave been 1.

Saturated with

Oxymuriatic acid . .	1·002 +
Sulphurous acid . .	1·040
Muriatic acid . . .	1·500
Ammoniacal . . .	1·666

Thus the water undergoes an expansion, so that the density of the gases absorbed is not in reality so great as it appears to be. The following table exhibits the real densities of these gases in the water.

Oxymuriatic acid . .	1·5
Sulphurous	$31·7 = 3^3$ nearly.
Muriatic	$344·0 = 7^3$
Ammonia	$468·0 = 8^3$

That these gaseous bodies combine chemically with water, cannot be doubted.

The simple gases have the property of combining with different solid bodies, and of forming compounds sometimes gaseous, sometimes liquid, and sometimes solid. Oxygen combines with two dozes of carbon, forming carbonic acid and carbonic oxide, both gazes; the first a product of combustion, the second a combustible oxide. It combines with three dozes of phosphorus, forming oxide of phosphorus, phosphorous acid and phosphoric acid, all of which are solid bodies. It unites likewise with three doses of sulphur, and forms oxide of sulphur, sulphurous acid, and sulphuric acid: the first a solid, the second a gas, the third a liquid. It combines in various proportions with the metals, and all the metallic oxide are solids.

Hydrogen appears to combine in at least two proportions with each of the other simple combustibles. It unites also with several of the metals, but the proportions have not been ascertained.

CHAP. II.

OF LIQUIDS.

A liquid is a fluid, not sensibly elastic, the parts of which yield to the smallest impression, and move easily upon each other. All liquids have a certain cohesive force by which their particles are retained together, and this force is much greater in mercury than in water. The following table exhibits a list of liquids with their relative specific gravities.

Water	1·000
Ethers	0·632 to 0·900
Petroleum	0·730 to 0·878
Volatile oils . . .	0·792 to 1·094
Alcohol	0·796
Fixed oils	0·913 to 0·968
Supersulphureted hydrogen	——
Nitric acid	1·583
Sulphuric acid	1·885
Phosphuret of sulphur .	——
Oxymuriate of tin . . .	——
Mercury	13·568

Most substances are rendered liquid by heat; but these are the only bodies that are permanently liquid in this country.

Some liquids may be mixed, and of course combine in any proportion whatever. In this respect they resemble the gases. The following is a list of these liquids:

Water with alcohol.
nitric acid.
sulphuric acid.

Alcohol with	ether.
Sulphuric acid with	nitric acid.
Fixed oils with	petroleum.
	volatile oils.
	fixed oils.
Volatile oils with	petroleum.
	volatile oils.

These liquids, when once mixed, form a homogeneous compound, and do not afterwards separate again. The union is attended with the evolution of heat, and with a certain degree of condensation, for the specific gravity is always greater than the mean.

The following table exhibits a list of those liquids that unite with each other only in certain proportions:

Water with	ether.
	volatile oils.
	oxymuriate of tin.
Alcohol with	volatile oils.
	petroleum.
	phosphuret of sulphur.
Ether with	volatile oils.
	petroleum.
Volatile oils with	petroleum.

The following table exhibits a list of the most remarkable liquids that do not sensibly combine:

Water with	petroleum.
	fixed oils.
	supersulphureted hydrogen.
Fixed oils with	alcohol.
	ether.
Mercury with	water.
	alcohol.
	ether.
	volatile oils.
	petroleum.

No doubt the action of liquids on each other depends upon their affinity. The first class have the greatest affinity for each other; that of the second is greater, and that of the third is less than the cohesion of the particles of each.

Water has the property of combining with a very great number of solid bodies. It combines with them in two ways. In the first way the solid retains its solidity while the water loses its liquid form. Such combinations are called *hydrates*. In this way water combines with sulphur, metallic oxides, earths, alkalies, many acids, all salts, hydrosulphurets, and many animal and vegetable substances. In the second way, the water dissolves the solid, and the whole becomes liquid. In this way it acts upon many acids, alkalies, earths, salts, and vegetable substances.

These combinations are all chemical, and the hydrates appear to be the most intimate. Their specific gravity is always greater than the mean, while the specific gravity of saline solutions is usually less than the mean.

The action of the other liquids on solids has been hitherto but imperfectly investigated.

CHAP. III.

OF SOLIDS.

Solids are bodies composed of particles that cohere together, and cannot be moved among themselves without the exertion of a force sufficient to destroy the cohesion of the body. They are very numerous, and their specific gravity varies more than that of gases or liquids. The following table exhibits the specific gravity of the most remarkable solids:

	Sp. gravity.
Charcoals	0·223 to 1·526
Vegetable bodies	0·240 to 1·354
Salts	0·273 to 7·176
Earths	0·346 to 4·842
Solid acids	0·667 to 3·391
Earthy compounds	0·680 to 4·815
Bitumens and solid oils	0·892 to 1·357
Fixed alkalies	1·336 to 1·708
Phosphorus	1·770
Carburets of iron	1·987 to 7·840
Sulphur	1·990
Glass	2·732 to 3·329
Carbon	3·518 to 3·531
Metallic sulphurets	3.225 to 10·000
Metals and alloys and oxides	0·600 to 23.00

The following solids combine with each other in any proportion whatever:

Sulphur with phosphorus.
Carbon with iron?
Metals with most metals.
Protoxide of antimony with sulphuret of antimony.
Earths with earths.
Earths with some metallic oxides.
Some earths with fixed alkalies.
Fixed alkalies with solid oils.
Solid oils with each other and with bitumen.

All these combinations are produced by means of heat; unless they be brought into fusion, or at least one of them, they do not combine.

The following table exhibits the principal solids which have been observed to unite only in determinate proportions:

Sulphur with metals:
some metallic oxides.
earths.
fixed alkalies?
Phosphorus with carbon.
metals.
some earths.
Acids with alkalies.
earths.
metallic oxides.

These combinations are more intimate than the preceding, they have been more accurately examined, and are better known. They never take place unless one of the bodies, at least, be brought first into a liquid state, either by means of heat, or by solution in water.

The salts are the most important of these combinations, and a vast number of experiments have been made in order to ascertain the proportions in which their constituents combine. The following table exhibits the general result of these experiments. The numbers represent the weight of the different acids and bases which neutralize each other respectively:

Acids.			
Sulphurous	50	Barytes	63
Oxalic	39·5	Strontian	37
Nitric	34	Potash	38
Sulphuric	31	Soda	23·3
Phosphoric	22	Lime	21·8
Muriatic	18	Magnesia	17·6
Carbonic	16·5	Ammonia	9
Phosphorous	16		

Suppose we wish to form sulphate of barytes—from the above table, it appears that we must unite together 31 parts by weight of sulphuric acid, and 63 parts of barytes.

From various experiments hitherto made, it appears that the supersalts contain twice as much acid, and the subsalts twice as much base, as the neutral salts. Suppose that a given quantity of sulphate of potash is composed of 100 potash, united with x of sulphuric acid, then supersulphate of potash is composed of 100 potash, united with $2\,x$ sulphuric acid. The triple salts appear to consist of two different salts united together. Thus alum may be considered as a compound of *sulphate of potash* and *sulphate of alumina.*

According to the old doctrine of affinity delivered by Bergman, all bodies capable of combining have an affinity for each other. This affinity is a constant force, which may be represented by numbers. Affinity is *elective;* that is to say, if a has a stronger affinity for m than b has, and if m be combined with b, forming a compound which we may represent by mb; a, upon being mixed with this compound, has the property of separating b completely from m, and taking its place so as to form a compound, ma, while b is entirely disengaged. This doctrine has been lately called in question by Berthollet, and the greatest part completely refuted. According to Berthollet, affinity is not elective, and never occasions decomposition, but only combination. The decompositions which take place, are owing to other causes, such as insolubility, elasticity, &c. though this new opinion renders Bergman's tables of decomposition, of little comparative value; yet as they are in some cases useful, and are often referred to, it has been thought worth while to subjoin them to this work.

TABLE OF CHEMICAL DECOMPOSITIONS.

I.
ALKALIES.

Sulphuric acid
Nitric
Muriatic
Phosphoric
Fluoric
Oxalic
Tartaric
Arsenic
Succinic
Citric
Formic
Benzoic
Acetic
Saclactic
Boracic
Sulphurous
Nitrous
Carbonic
Prussic

II.
BARYTES AND STRONTIAN.

Sulphuric
Oxalic
Succinic
Fluoric
Phosphoric
Saclactic
Nitric
Muriatic
Suberic
Citric
Tartaric
Arsenic
Benzoic
Acetic
Boracic
Sulphurous
Nitrous
Carbonic
Prussic

III.
LIME.

Oxalic
Sulphuric
Tartaric
Succinic
Phosphoric
Saclactic
Nitric
Muriatic
Suberic
Fluoric
Arsenic
Citric
Malic
Benzoic
Acetic
Boracic
Sulphurous
Nitrous
Carbonic
Prussic

IV.
MAGNESIA

Oxalic
Phosphoric
Sulphuric
Fluoric
Arsenic
Saclactic
Succinic
Nitric
Muriatic
Tartaric
Citric
Malic
Benzoic
Acetic
Boracic
Sulphurous
Nitrous
Carbonic
Prussic

V.
ALUMINA.

Sulphuric
Nitric
Muriatic
Oxalic
Arsenic
Fluoric
Tartaric
Succinic
Saclactic
Citric
Phosphoric
Benzoic
Acetic
Boracic
Sulphurous
Nitrous
Carbonic
Prussic

VI.
OXIDE OF GOLD.

Muriatic acid
Nitric
Sulphuric
Arsenic
Fluoric
Tartaric
Phosphoric
Prussic

VII.
OXIDE OF SILVER.

Muriatic acid
Oxalic
Sulphuric
Saclactic
Phosphoric
Sulphurous
Nitric
Arsenic
Fluoric
Tartaric
Citric
Formic
Acetic
Succinic
Prussic
Carbonic

VIII.
OXIDE OF MERCURY.

Muriatic
Oxalic
Succinic
Arsenic
Phosphoric
Sulphuric
Saclactic
Tartaric
Citric
Sulphurous
Nitric
Fluoric
Acetic
Boracic
Prussic
Carbonic

IX.
OXIDE OF COPPER.

Oxalic acid
Tartaric
Muriatic
Sulphuric
Saclactic
Nitric
Arsenic
Phosphoric
Succinic
Fluoric
Citric
Formic
Acetic
Boracic
Prussic
Carbonic

X.
OXIDE OF IRON.

Oxalic acid
Tartarous
Camphoric
Sulphuric
Saclactic
Muriatic
Nitric
Phosphoric
Arsenic
Fluoric
Succinic
Citric
Formic
Acetic
Boracic
Prussic
Carbonic

XI.
OXIDE OF NICKEL.

Oxalic acid
Muriatic
Sulphuric
Tartaric
Nitric
Phosphoric
Fluoric
Saclactic
Succinic
Citric
Formic
Acetic
Arsenic
Boracic
Prussic
Carbonic

XII.
OXIDE OF TIN.

Tartaric acid
Muriatic
Sulphuric
Oxalic
Arsenic
Phosphoric
Nitric
Succinic
Fluoric
Saclactic
Citric
Formic
Acetic
Boracic
Prussic

XIII.
OXIDE OF LEAD.

Sulphuric acid
Saclactic
Oxalic

- Arsenic
- Tartaric
- Muriatic
- Phosphoric
- Sulphurous
- Suberic
- Nitric
- Fluoric
- Citric
- Formic
- Acetic
- Boracic
- Prussic
- Carbonic

XIV.
OXIDE OF ZINC.

- Oxalic acid
- Sulphuric
- Muriatic
- Saclactic
- Nitric
- Tartaric
- Phosphoric
- Citric
- Succinic
- Fluoric
- Arsenic
- Formic
- Acetic
- Boracic
- Prussic
- Carbonic

XV.
OXIDE OF BISMUTH.

- Oxalic acid
- Arsenic
- Tartaric
- Phosphoric
- Sulphuric
- Muriatic
- Benzoic
- Nitric
- Fluoric
- Saclactic
- Succinic
- Citric
- Formic
- Acetic
- Prussic
- Carbonic

XVI.
OXIDE OF ANTIMONY.

- Muriatic acid
- Benzoic
- Oxalic
- Sulphuric
- Nitric
- Tartaric
- Saclactic
- Phosphoric
- Citric
- Succinic
- Fluoric
- Arsenic
- Formic
- Acetic
- Boracic
- Prussic
- Carbonic

XVII.
OXIDE OF ARSENIC.

- Muriatic acid
- Oxalic
- Sulphuric
- Nitric
- Tartaric
- Phosphoric
- Fluoric
- Saclactic
- Succinic
- Citric
- Formic
- Arsenic
- Acetic
- Prussic

XVIII.
OXIDE OF COBALT.

- Oxalic acid
- Muriatic
- Sulphuric
- Tartaric
- Nitric
- Phosphoric
- Fluoric
- Saclactic
- Succinic
- Citric
- Formic
- Acetic
- Arsenic
- Boracic
- Prussic
- Carbonic

XIX.
OXIDE OF MANGANESE.

- Oxalic acid
- Citric
- Phosphoric
- Tartaric
- Fluoric
- Muriatic
- Sulphuric
- Nitric
- Saclactic
- Succinic
- Tartaric
- Formic
- Acetic
- Prussic
- Carbonic

XX.
OXIDE OF TITANIUM.

- Phosphor. acid
- Arsenic
- Oxalic
- Sulphuric
- Muriatic
- Nitric
- Acetic

XXI.
SULPHURIC ACID.

- Barytes
- Strontian
- Potash
- Soda
- Lime
- Magnesia
- Ammonia
- Glucina
- Yttria
- Alumina
- Zirconia

XXII.
SULPHUROUS ACID.

- Barytes
- Lime
- Potash
- Soda
- Strontian
- Magnesia ⎫
- Ammonia ⎭
- Glucina
- Alumina
- Zirconia

XXIII.
PHOSPHORIC ACID.

- Barytes
- Strontian
- Lime
- Potash
- Soda
- Ammonia
- Magnesia
- Glucina
- Alumina
- Zirconia

XXIV.
PHOSPHOROUS ACID.

- Lime
- Barytes
- Strontian
- Potash
- Soda
- Ammonia
- Glucina
- Alumina
- Zirconia

XXV.
CARBONIC ACID.

- Barytes
- Strontian
- Lime
- Potash
- Soda
- Magnesia
- Ammonia
- Glucina
- Zirconia

XXVI.
NITRIC ACID.

- Barytes
- Potash
- Soda
- Strontian
- Lime
- Magnesia
- Ammonia
- Glucina
- Alumina
- Zirconia

XXVII.
XXVIII.
MURIATIC & ACETIC ACIDS.

- Barytes
- Potash
- Soda
- Strontian
- Lime
- Ammonia
- Magnesia
- Glucina
- Alumina
- Zirconia

XXIX.
OXYMURIATIC ACID.

- Potash
- Soda
- Barytes
- Strontian
- Lime

Ammonia
Magnesia
Alumina

XXX. XXXI.
XXXII.
XXXIII.
Fluoric, Boracic, Arsenic, & Tungstic Acids.

Lime
Barytes
Strontian
Magnesia
Potash
Soda
Ammonia
Glucina
Alumina
Zirconia

XXXIV.
Oxalic Acid.

Lime
Barytes
Strontian
Magnesia
Potash
Soda
Ammonia
Alumina

XXXV.
Citric Acid.

Lime
Barytes
Strontian
Magnesia
Potash
Soda
Ammonia
Alumina
Zirconia

XXXVI.
Benzoic Acid.

Potash
Soda
Ammonia
Barytes
Lime
Magnesia
Alumina

XXXVII.
Succinic Acid.

Barytes
Lime
Potash
Soda
Ammonia
Magnesia
Alumina

XXXVIII.
Camphoric Acid.

Lime
Potash
Soda
Barytes
Ammonia
Alumina
Magnesia

XXXIX.
Suberic Acid.

Barytes
Potash
Soda
Lime
Ammonia
Magnesia
Alumina

XL.
Prussic Acid.

Barytes
Strontian
Potash
Soda
Lime
Magnesia
Ammonia

XLI.
Fixed Oils.

Lime
Barytes
Fixed alkalies
Magnesia
Ammonia
Oxide of mercury
Other metallic oxides
Alumina

THE END.

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